

**Exploration of the patterns of microbial colonization of
intravascular devices in severely ill patients**

By

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Candidate Declaration

I certify that the thesis entitled: “*Exploration of the patterns of microbial colonization of intravascular devices in severely-ill patients*” submitted for the fulfilment of the degree of Doctorate in Philosophy is the result of my own research, and contains no material which has been accepted for a degree or diploma by this university or any other institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person except where due acknowledgement is made in the text of the thesis.

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The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Human Research Ethics Committee (Tasmania) Network.

David Boon Chai Koh, 26th August 2011

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List of publications and presentations

Publications arising out of this work

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Koh, D.B.C., Robertson, I.K., Watts, M. and Davies, A.N. A retrospective study to determine whether accessing frequency affects the incidence of microbial colonisation in peripheral arterial catheters. *Anaesthesia and Intensive Care*, 2010. **38**(4): p. 678-84.

Koh, D.B.C., Robertson, I.K., Watts, M., Davies, A.N.. “Where does colonization occur in intravascular devices? A prospective study to determine the density of microbial colonization on the external and internal surfaces of concurrently-sited intravascular devices.” *American Journal of Critical Care*, 2011. (in press).

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List of abbreviations

AC(s)	arterial catheter(s)
AICA	Australian Infection Control Association
APACHE	Acute Physiology And Chronic Health Evaluation
cm	centimetres
CDC	Centers for Disease Control
CFU(s)	colony forming unit(s)
CNE(s)	clinical nurse educator(s)
CRBSI	catheter-related bloodstream infection
CVC(s)	central venous catheter(s)
DEM	Department of Emergency Medicine
HR	hazards ratio
IAD(s)	intravascular access device(s)
ICU(s)	intensive care unit(s)
IQR	interquartile range
IVD(s)	intravascular device(s)
mm	millimetres
OR	odds ratio
OT	operating theatre
PICC(s)	peripherally-inserted central catheter(s)
RN(s)	registered nurse(s)
SAPS	Simplified Acute Physiology Score
SD	standard deviation
USA	United States of America
US	United States
\$	dollars
95% CI	95 percent confidence intervals

Abstract

Innovations in healthcare have led to survival of a higher proportion of critically-ill, elderly and immuno-compromised patients. Intravascular devices (IVDs) are indispensable in providing safe, reliable vascular access and continuous haemodynamic monitoring of these patients in the intensive care unit. Unfortunately, many healthcare-acquired or nosocomial infections in severely ill patients can be caused by the very medical devices that are implanted to provide life-sustaining care.

IVDs comprising peripheral arterial catheters (ACs), non-tunnelled short-term central venous catheters (CVCs) and peripherally-inserted central catheters (PICCs) breach the skin and provide a potential avenue for external micro-organisms to invade the tissue or bloodstream. All IVDs are associated with a risk of both local and systemic catheter-related bloodstream infection (CRBSI).

Few studies have been conducted on colonization rates of ACs and their potential to cause CRBSI. Therefore, in a preliminary study, we compared the colonization rates of ACs with CVCs which were concurrently managed in a defined cohort of patients. This study revealed that both AC colonization and CRBSI rates were comparable to those in concurrently-sited and identically managed CVCs. Therefore, ACs should be accorded the same degree of importance as CVCs as a potential source of sepsis. This observation led to the development of 3 studies to critically examine a number of aspects of this problem.

Study 1: To determine the predominant mechanism of ACs colonization by comparing ACs accessing frequency to colonization rate

Study 2: To determine the degree of microbial colonization on the external and internal surfaces of concurrently-sited IVDs and to establish if microbial growth is greater on a particular segment of the IVDs at the time of removal.

Study 3: To determine the degrees of concordance of nursing care and management of IVDs with Centers for Disease Control and Prevention (CDC) guidelines and institutional protocols, and how the deficit in adherence to these protocols may impact on IVD colonization.

There are currently three explanations for the process of microbial colonization in IVDs. The first suggests colonization by micro-organisms occurs on the outside of the catheter, either via downward colonization of micro-organisms from the patient's skin surface on the outside surface of the catheter, or via upward colonization where the micro-organisms are inoculated on the tip of the IVD at the time of insertion. The second suggests micro-organisms are introduced via the inside surface of the IVD, either via a contaminated infusate, or via contamination of the port or hub connected to the IVD. The third suggests that micro-organisms are disseminated from some other part of the patient's body, and carried via the bloodstream to both the inside and outside surfaces of the catheter.

A common assumption is that the more frequently an IVD is accessed, the greater the likelihood of contamination and colonization. My first study sought to determine if accessing frequency had an influence on the rate of colonization in ACs, thereby testing the influence of the second mechanism (i.e. contamination of hub or infusate) on IVD colonization. In this study we used some of the data from the prior surveillance cohort with additional data collection. No significant differences were found between the rates of accessing the ACs and their colonization when adjusted for confounding, continuous variables. Accessing frequency of an AC did not appear to be a major predisposing factor for the likelihood of colonization, suggesting that the second mechanism of IVD colonization via the intra-luminal route was less common in the context of reasonable application of aseptic practices.

My next study focused on determining the degree of microbial colonization on the external and internal surfaces of concurrently-sited IVDs, and to establish if a relative difference in microbial growth existed on a particular segment of the IVD at the time of removal. This involved determining the colony count at six different sites on each individual IVD, allowing repeated-measures comparison of each IVD with itself. Degree of colonization was greatest at the proximal, external surface of the intravascular segment of all IVD types compared to the middle or distal segments. Overall degree of colonization on the IVDs' internal surfaces was also less than on the external surfaces. This suggests that the wound site created by IVD insertion may be a significant source of colonization and CRBSI. This finding raised the question if IVD wound-site care practices might contribute to the likelihood of colonization.

It is apparent that IVD colonization is caused by multiple factors, one being the environment in which these IVDs are managed and cared for on a daily basis. Practice guidelines and institutional infection control protocols provide a reference point for nurses involved with the care and management of IVDs to implement best practice. However, little is known about how closely nurses adhered to the guidelines and protocols when caring and managing IVDs, and if any variations in practice contributes to increased microbial colonization in IVDs. Therefore, the final study sought to determine the degree of concordance of current nursing practice to evidence-based practice guidelines, as a proxy for actual adherence to protocols, and how partial or non-adherence to protocols may impact on colonization. This study showed that there was less than ideal adherence to practice protocols, and that for some aspects of practice, adherence to protocol by intensive care unit nurses (who manage IVD care daily), was less than those who had less experience of IVD care. Clearly, nurses had different preferences for sourcing advice and information about IVD care practices. Future research would be required to determine whether this differential adherence to protocols and guidelines was associated with poorer outcomes, better outcomes, or no outcome differences.

In summary, the major findings of this work are:

- 1) Establishing that AC colonization rates and CRBSI rates were similar to CVCs, reiterating the need to accord the same degree of importance to ACs as CVCs as a potential source of sepsis.
- 2) Dispelling the notion that the more frequently an IVD is accessed, the greater the likelihood of contamination and colonization.
- 3) IVD colonization via the intra-luminal route was less common when compared to the mechanism of microbial colonization on the external surface of the IVD.
- 4) Microbial colonization is heaviest on the external surface of the proximal segment of all IVD types compared to the middle or distal segments, and that overall degree of colonization on the IVDs' internal surfaces was also less than on the external surfaces.
- 5) Discrepancies in concordance between the CDC guidelines and current nursing practice exist
- 6) A knowledge-practice gap exists because the access to evidence-based protocols intended to provide vital information and guide nursing practice may be hindered by the choice of end-users who may not use these protocols.

CHAPTER 1

General introduction

Innovative advances in healthcare have resulted in a higher proportion of critically-ill, elderly and immuno-compromised patients being treated. The advent of modern medicine in both developed and developing countries brings with it increasing numbers of invasive technological procedures and therapies [1, 2]. Safe and reliable vascular access is an essential requirement for the management of critically and chronically ill patients in modern-day medicine [3, 4].

IVDs are indispensable tools that provide safe, reliable, vascular access and continuous haemodynamic monitoring of patients in the intensive care unit (ICU) [5]. Their usage has substantially increased not only in the hospital setting, but also in the outpatient setting [6]. Unfortunately, many nosocomial or healthcare-acquired infections in severely ill patients are attributed to the very medical devices that are implanted to provide life-sustaining care [7-9]. All IVDs breach the patient's skin integrity and potentially provide an avenue for external micro-organisms to invade the tissue or bloodstream, increasing the risk of both local infection and CRBSI [7, 8, 10, 11].

CRBSI, which form part of healthcare-acquired infections, incur human, economic and social costs [12]. Costs include treating the infection (e.g. antibiotics, surgery), increased laboratory investigations, extended lengths of stay in intensive care units, additional care costs in the ward, and also in the community after hospital discharge [13-15]. Social costs include the loss of work productivity, dependence on social welfare and support mechanisms, and the experience of suffering and disability [16].

My occupation as a critical care registered nurse (RN) working in the ICU has allowed me to care for numerous patients who may have succumbed to the debilitating effects of CRBSI.

While there are several preventive measures implemented to contain the incidence of CRBSI in the ICU, IVD colonization, a precursor of CRBSI, is common. There is a wealth of literature about the pathophysiological processes of infection, how the human body interacts with invading microbes, and how foreign objects inserted into the human body, such as IVDs provide a link between the two pathological developments [5, 10, 17]. However, it appears that the understanding and knowledge of CRBSI and IVD colonization may have not been used in a very systematic manner to drive forward the investigation of IVD colonization as cause of disease, to produce an effective methodology to control it. This thesis attempts to identify the gaps in what is understood about IVD colonization, and accord some clarity to the issue of CRBSI.

The multi-factorial elements contributing to the risk of IVD colonization and CRBSI has given rise to many strategies and recommendations to guide the care and management of IVDs in the clinical area [18]. Many of these are incorporated into guidelines or protocols, which provide registered nurses (RNs) with an evidence base to support clinical decision-making in caring for and managing patients with IVDs. It is however, unknown how concordant RNs are with these guidelines when managing and caring for patients with IVDs in the clinical area.

This thesis will provide an inquiry into current nursing care and management of IVDs in the clinical area, and attempt to identify any deficits which may affect the delivery of quality healthcare in the clinical area. The details of the research will be outlined next.

1.1 Research purpose

The purpose of this research is to provide a broader understanding on how the process of microbial colonization takes place on IVDs.

1.2 Research problem

The research problem identified is:

There are currently three theories explaining the likely routes of IVD colonization, but there is a lack of knowledge of how microbial colonization develops on the entire length of the IVD, and it is unclear which of one of these three routes is more predominant than the others.

1.3 Research questions

The questions that arise from the research problem are:

Does microbial colonization occur on all IVDs?

How do the colonization rates compare between ACs, CVCs and PICCs?

Is there a more commonly-occurring route of microbial colonization in IVDs?

Is there a relative difference in microbial growth existing on a particular segment of IVD at the time of its removal, and what are the implications of this finding?

How concordant to guidelines and protocols is the routine care and management of IVDs in the clinical areas, and how do these findings impact on microbial colonization?

1.4 Research aim

The aim of the research is to explore the mechanisms of occurrence of IVD microbial colonization in order to achieve insights that might be useful in its prevention. Specifically, the research examines the process that occurs inside the body of the patient when colonization occurs; and what aspects of nursing practice, occurring outside the patient's body, might influence microbial colonization.

1.5 Research objectives

The objectives of the research are:

- To compare the colonization rates of ACs with CVCs in a cohort of patients

- To determine the predominant mechanism of AC colonization by comparing AC accessing frequency to colonization rate
- To determine the degree of microbial colonization on the external and internal surfaces of concurrently-sited IVDs, and to establish if microbial growth is greater on a particular segment of the IVDs at the time of removal
- To determine the degrees of concordance of nursing care and management of IVDs with current guidelines and institutional protocols, and how if any deficit in adherence to these protocols may impact on IVD colonization

1.6 Development of thesis

This thesis is comprised of work published in peer reviewed journals between 2008 and 2010 by David Koh and duly acknowledged co-authors, and recently completed work which has been submitted or about to be submitted for publication. The impetus of my research arose from my involvement in a service surveillance audit conducted by Dr John Gowardman, the then Director of Intensive Care in the Launceston General Hospital; which focused on monitoring colonization and CRBSI rates in CVCs. Findings from this preliminary study led to the development of three other studies which comprise the main body of work being undertaken for this thesis at the School of Human Life Sciences, University of Tasmania.

Chapter 2 is a review of the literature on IVDs, microbial colonization, and CRBSI. It explores the indispensability and risk factors associated with IVDs in critical care. The chapter also examines the phenomenon of microbial colonization in IVDs, and how this process can sometimes cause CRBSI. An overview of CRBSI is presented and the gaps where there is a lack of further inquiry and knowledge are highlighted.

Chapters 3 to 6 contain the descriptions of the four studies which make up this thesis. Chapters 3 and 4 are peer-reviewed papers reformatted and reproduced in their published

entirety, which covers the aims, methodology, results, discussion and conclusion of each study. Chapter 5 is presented in the format of a submitted manuscript which is in press awaiting publication by the American Journal of Critical Care. Chapter 6 is a prepared manuscript in the format for submission to the Journal of Advanced Nursing. Some repetition between the chapters is the result of these chapters being written as scientific papers for publication in various peer-reviewed journals (details on page ix).

Chapter 7 brings together the key findings of the four studies and integrates a general discussion to answer the questions raised in this thesis. It offers suggestions for future research.

CHAPTER 2

Literature Review on Intravascular Devices, Microbial Colonization, and Intravascular Devices-Related Bloodstream Infection

2.1 Introduction

This chapter provides an overview and critique of the literature surrounding the use of IVDs and CRBSI. The usage, physical differences, and complications of ACs, CVCs and PICCs will be discussed. The process of biofilm formation leading to microbial formation on IVDs will be examined. CRBSI definitions, incidence, outcome, pathogenesis and risk factors will be reviewed while preventive measures pertaining to catheter selection, insertion techniques, pre- and post-insertion care and treatment options will also be discussed.

2.2 Intravascular devices

2.2.1 IVD usage

IVDs are used regularly in critical care, most frequently in ICUs [19] with recent trends of increased usage in the community as well [8]. The precise number of IVDs used internationally is unknown, however estimates of IVDs usage in the ICUs of the United States of America (USA) were at least 150 million inserted annually [20], with 15 million IVD days of treatment per year in the USA alone [21]. IVD usage figures in Australia were harder to obtain, but can be estimated at 345,000 IVDs used annually based on data extrapolated from these studies [22, 23].

2.2.2 Risks associated with IVD usage

Mortality rates partially attributed to healthcare-acquired bloodstream infections were reported to be as high as 25% [24, 25] or 90,000 deaths in the USA alone [26]. Patients with CRBSI have found an increased length of ICU stay between 7 and 19.1 days, and an extended

hospitalization stay of between 2-3 weeks [16, 27, 28]. Treatment of CRBSI incurs significantly higher institutional costs estimated to range between 3,000 United States (US) dollars (\$) to US\$ 56,167 per case in the USA [21, 29, 30], contributing to an annual financial burden of US\$ 6.5 billion [26]. In Australia, the estimated cost of healthcare-acquired infections related to IVD-related bloodstream infections is estimated to cost the Australian government an extra \$32 to \$54 million per year in healthcare expenditure [23].

2.2.3 Types of IVDs

Many types of IVDs are used to obtain vascular access in the health care system. Terminology used in the identification of IVDs is complicated, because naming tends to be based on the different features of the IVD, its insertion site, or aspects relevant to communication between healthcare professionals for the management of IVDs [31]. For example, an IVD can be designated by the type of vessel it resides in (e.g. peripheral venous, central venous, or arterial); its intended lifespan (e.g. temporary or short-term versus permanent or long-term); its site of insertion (e.g. subclavian, femoral, internal jugular, peripherally inserted central, peripheral); its pathway from skin to vessel (e.g. tunnelled versus non-tunnelled); its physical length (e.g. long versus short); its physical characteristics (single lumen versus multiple lumens); or by some special characteristic the IVD possess (e.g. cuff versus non-cuffed, impregnated with heparin, antibiotics or antiseptics). Each is designed slightly differently to suit its purpose (e.g. high or low volume infusions; long or short-term use) and intended insertion site (e.g. central or peripheral; venous or arterial) [31]. This thesis will focus primarily on peripheral ACs, CVCs (non-cuffed and non-tunnelled) and PICCs.

2.2.4 ACs, CVCs and PICCs

ACs are inserted peripherally into the radial or femoral artery to allow continuous monitoring of blood pressure and blood gas analyses [32-36]. ACs vary in length (3 centimetres (cm) -

20cm) and their selection and usage is determined by the site of insertion and operators' preferences (Table 1).

Table 1: IVDs used for venous and arterial access

IVD type	Insertion site	Length	Current opinion
ACs	Usually radial artery; femoral, brachial, axillary and posterior tibial arteries are sometimes used	3cm - 20cm	Low infection risk; rarely associated with bloodstream infection
CVCs (non-tunnelled)	Percutaneously inserted into central veins (subclavian, internal jugular, or femoral)	20cm - 30cm depending on patient's size	Usually for short to medium term use (≥ 1 day to ≤ 14 days) Account for majority of CRBSI
PICCs	Inserted into basilic, cephalic, or brachial veins and their tips enter the superior vena cava	55cm - 60cm depending on patient's size	Lower rate of infection than non-tunnelled CVCs Suitable for long term use ≥ 14 days

Adapted from Centers for Disease Control and Prevention [31]

CVCs are inserted percutaneously with their tips usually ending within a major vein. They measure 20cm - 30cm, have between three to five lumens, and are used for the administration of intravenous fluids and electrolytes, blood transfusion, total parenteral nutrition, chemotherapy, and antibiotic therapy; as well as indirect monitoring of cardiac function and hydration status via central venous pressure [25]. CVCs, particularly anti-microbial CVCs are more expensive than peripheral catheters [37] (Table 1).

PICCs serve the same functions as CVCs but are thinner in diameter (1.4 millimetres (mm) - 1.77mm), have smaller lumens (18G - 20G), and are longer than CVCs (55cm - 60cm) [25]. PICCs are either single-lumen or double lumen, and when compared to CVCs present less risk of haemorrhage or pneumothorax [9, 38]. PICCs are usually inserted in the antecubital fossa of either arm or the brachial site (Table 1).

There is a real risk for an IVD to become colonized and hence increase infection risk the longer the duration it is left *in situ* [35, 39, 40]. These IVDs were found to have coatings of fibrin and thrombus formations along their surfaces, increasing the susceptibility of the IVD to microbial colonization.

2.3 Microbial colonization

2.3.1 Biofilm formation

A biofilm is not a static, flimsy, slime layer but rather is a coordinated living community of micro-organisms which may be composed of multiple species of bacteria and their secreted polysaccharide matrix and components deposited from bodily fluids [17, 41]. A conditioning film, dependent on the type of fluid the device interacts with, is formed on the surface of the IVD [10, 42, 43]. For example, IVDs rapidly acquire a sleeve of fibrin and fibronectin, components commonly found in blood, whereas urinary catheters tend to become encrusted with protein, electrolytes, and other organic molecules from the patient's urine [17, 44]. Once this conditioning film is formed, the IVD surface becomes susceptible to microbial attachment and adhesion of micro-organisms to the IVD surface will depend on long-range bacteria-biomaterial surface interactions such as Van Der Waal's forces, electrostatic interactions and hydrophobic interactions [10, 45]. These forces also influence protein adhesion on the surface of the IVD [10].

The plastic biomaterials commonly used to make IVDs are hydrophobic, thus facilitating initial microbial attachment. Many micro-organisms have hydrophobic components which enable them to attach to the IVD surface by removing the water molecules between them [10]. Initial bacterial adhesion, which is non-specific, is followed by specific adhesion, mediated by an adhesin receptor, which binds to the conditioning film's extracellular host proteins such as fibronectin, fibrinogen, fibrin, collagen, laminin, vitronectin, and elastin;

strongly fixing the micro-organism to the surface of the catheter [46-48]. Other micro-organism cell structures such as pili and flagella also facilitate attachment.

Microbial colonization occurs when attached or sessile micro-organisms divide to form micro-colonies of bacteria which in turn secrete large amounts of extracellular polysaccharide matrix (or slime) forming the architectural structure of the biofilm [43]. Slime is an extensive and diffuse polyanionic matrix that surrounds the micro-organisms' cells [17, 45]. The cells in their three-dimensional matrix form thick pillars separated by fluid-filled spaces [43]. The pillars can be compared to as apartment buildings, and the fluid-filled spaces as streets between buildings through which the organisms receive nutrients, diffuse away wastes, and send chemical signals to each other [43]. This slimy substance protects the bacteria against host defence systems and antimicrobial agents, and clumping factor produced by some micro-organisms such as *Staphylococcus aureus*, makes it thrombogenic [10, 17].

Other species of bacteria may move into the biofilm, and interaction by quorum sensing mechanisms between the species can in turn produce different micro-environments within a given biofilm, facilitating plasmid exchange and enhancing antimicrobial resistance [17, 49-51]. If environmental conditions should become unfavourable; such as the exhaustion of nutrients or overcrowding, sessile micro-organisms can detach themselves and become free-floating, or planktonic in the bloodstream of the patient [17].

2.3.2 Types of micro-organisms

The types of micro-organisms cultured are varied and change over time [31]. Coagulase-negative *Staphylococci* are the main micro-organisms cultured from IVDs in several studies [27, 52-55]. Some other studies found Gram-negative *bacilli* species [53, 54, 56, 57] and *Candida* species [38, 57, 58] as the main micro-organisms of colonization along with *Staphylococcus epidermidis* [58, 59], *Staphylococcus aureus* [11, 59, 60], *Streptococcus*

species [61], *Enterococcus* [57, 58], *Coliforms* [11, 61], *Corynebacterium* species [60], and *Pseudomonas* species [62, 63]. While it is interesting to take into account the different microbial species cultured, it is also worthwhile investigating further the relationship between the micro-organisms co-habiting in the same IVD which may influence the degree of virulence, thereby impacting on CRBSI.

2.3.3 Mechanisms of microbial colonization

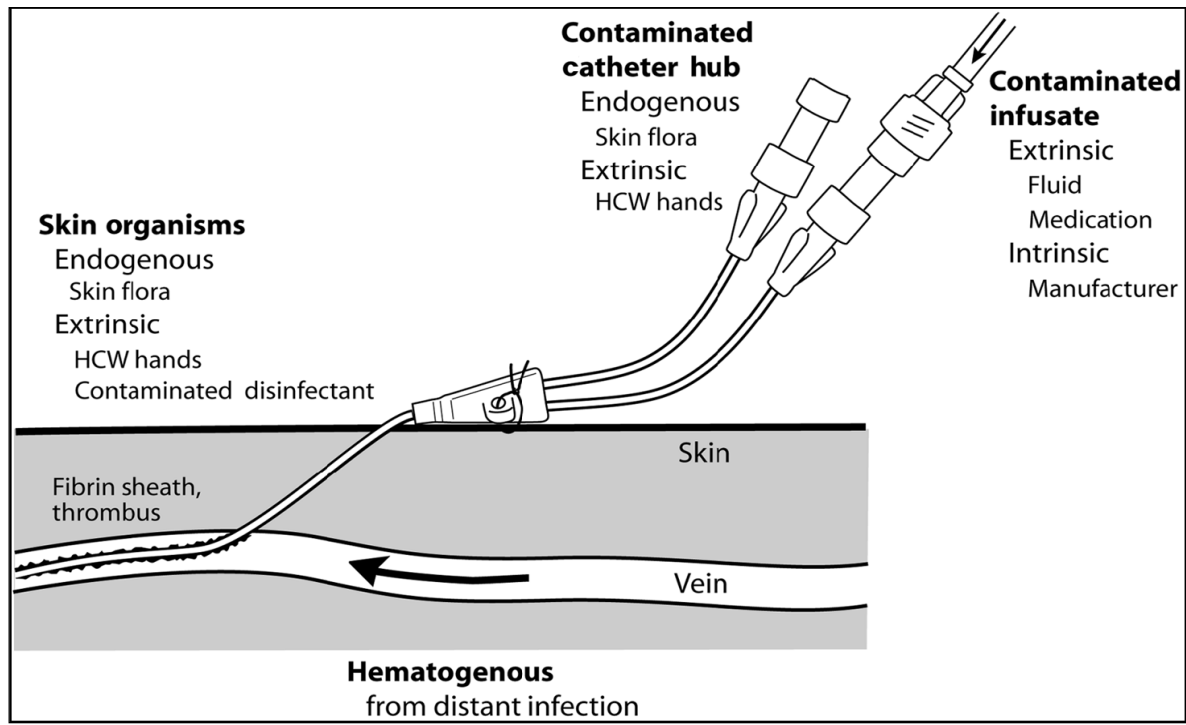
Micro-organisms enter the bloodstream at the time of IVD insertion or at any time during therapy, from endogenous sources such as skin flora, or through extrinsic sources such as contaminated health care workers' hands, inadequate or incorrect skin disinfection prior to IVD insertion or when the IVD is *in situ* (Figure 1).

There are currently three explanations describing the process of microbial colonization in IVDs. The first suggests colonization by micro-organisms occurs on the outside of the catheter (extra-luminally), either via downward colonization of micro-organisms from the patient's skin surface on the outside surface of the catheter [17, 20, 45, 57, 64-66] or via upward colonization where the micro-organisms are inoculated on the tip of the IVD at the time of insertion [67] (Figure 1).

The second mechanism suggests micro-organisms are introduced via the inside surface of the IVD (intra-luminally), either via contamination of the port or hub connected to the IVD [59, 61, 64, 68-70], or via a contaminated infusate, [71, 72] although this latter source is now relatively rare (Figure1).

The third suggests that micro-organisms are disseminated from some other part of the patient's body, and carried via haematogenous spread from a metastatic location such as a lung or brain abscess, endocarditis, or osteomyelitis via the bloodstream to both the inside and outside surfaces of the catheter [32, 36, 73] (Figure 1).

Figure 1: The various routes where micro-organisms enter the bloodstream via an intravascular device and cause bloodstream infection.



Adapted from Crnich and Maki [3] HCW = health care worker

The literature has revealed three mechanisms of IVD colonization, however, it remains unclear if one major route of IVD colonization occurs more frequently than another major route of colonization. While some past studies have suggested that microbial colonization originated from the skin surface surrounding the point of IVD entry, tracking downwards the external surface of the IVD, these studies fall short in examining the IVD in its entirety, failing to determine if there was a pattern of heavier microbial colonization on a particular segment of the IVD.

2.3.4 Incidence of Colonization

Microbial colonization is a common occurrence, affecting about 19-31% of all IVDs inserted in Australian hospitals [74] and between 14-71% in other hospitals worldwide [75]. While colonization has no known direct adverse effects, it is widely accepted as the harbinger of the pathogenesis of CRBSI or catheter-related bacteraemia, which is a much more serious

healthcare-acquired infection [1, 31]. Colonization is a more frequent event compared to CRBSI, and is therefore regarded as a necessary but not sufficient condition for the diagnosis of CRBSI. Although the focus of this thesis is on the exponential growth of micro-organisms on the surfaces of IVDs to determine if a pattern or trend of microbial growth exists, it is necessary to review the literature on CRBSI and expose how a lack of understanding in the pattern of microbial colonization has led to an array of diagnostic techniques for CRBSI which may not always be effective. Consequently, different diagnostic techniques have resulted in different ways of presenting data and results, adding to more confusion to the complexities that CRBSI already present.

2.4 IVD-Related Bloodstream Infection

2.4.1 Definitions

There has been much diversity of terminologies and definitions used to describe IVD-related infections, and some reviewers have called for a standardized set of definitions to be used to reduce confusion [67]. The words “related”, “associated”, and “acquired” have been used interchangeably in various literature [31] and the identification of organisms from cultures of the catheters has also been variously described in literature as “catheter contamination” [70, 76], “catheter tip infection” [74, 77] and “catheter infection” [70, 74, 78]. The Australian Infection Control Association (AICA) has attempted to standardise the definition of bloodstream infection in Australia [79] by adapting definitions from the Centers for Disease Control and Prevention (CDC), and the Nosocomial Infections Surveillance System in USA, and re-classifying bloodstream infections according to the place of acquisition, namely “healthcare-associated”, “community-associated”, and “maternally-acquired” [79]. AICA has also proposed methods of calculating bloodstream infection rates [79] in these areas but because of its complexity, very few hospitals use them, preferring to adopt the CDC classifications of IVD-related infections in Table 2.

Table 2: CDC definitions for catheter-related infection

Colonized catheter:	Growth of ≥ 15 colony forming units (semi-quantitative culture) from a proximal or distal catheter segment in the absence of accompanying clinical symptoms.
Exit site infection	Erythema, tenderness, induration, or purulence within 2cm of the skin at the exit site of the catheter.
Tunnel infection	Erythema, tenderness, and induration in the tissues overlying the catheter and > 2 cm from the exit site.
Catheter-related bloodstream infection (CRBSI)	Isolation of the same organism (i.e. identical species, antibiogram) from a semi-quantitative culture of catheter segment and from blood (preferably drawn from a peripheral vein) of a patient with accompanying clinical symptoms of BSI and no apparent source of infection. In the absence of laboratory confirmation, defervescence after removal of an implicated catheter from a patient with BSI may be considered indirect evidence of CRBSI

Adapted from Centers for Disease Control and Prevention [31]

In keeping with the CDC definition, it has become increasingly well accepted practice to define a positive catheter culture with ≥ 15 colony forming units (CFUs) as catheter colonization [31]. A catheter is colonized based on the laboratory criteria of a minimum of ≥ 15 CFUs using a semi-quantitative culture technique [80] or ≥ 100 CFUs using a qualitative culture technique [31, 81, 82]. Catheter contamination is sometimes clarified by a growth of < 15 CFUs from the catheter segment cultured [76]. The CDC definitions for “exit site infection” and “tunnel infection” are clinically based and relatively straightforward, and even if they do occur, such infections are however classified as wound infections in the presence of a foreign body rather than CRBSI because of the diagnostic criteria applied to diagnose CRBSI.

IVD contamination is mostly attributed to skin commensals around the exit site of the IVD. Current CDC recommended protocols of dressing changes using chlorhexidine 0.5% in 70% alcohol appear to contain IVD contamination to a minimum. However, a contaminated IVD can develop into a colonized IVD (≥ 15 CFUs) through time, and the offending micro-organism is eradicated with antibiotic therapy to prevent further microbial development into more serious infections such as CRBSI, exit site infection, or tunnel

infection. Microbial IVD colonization is contained by the prompt removal of IVDs when their usage have ceased, routine IVD replacement (after 10-14 days *in situ* as practised in some clinical areas) and also by the increased use of antibiotic-impregnated IVDs. While not all colonized IVDs will cause CRBSI, by definition CRBSI can only occur from a colonized IVD, and therefore the surveillance of IVD colonization rates may be a useful preventive measure of reducing the risk of CRBSI by identifying rising trends in IVD colonization whose cause might be identified and eliminated. A patient with a heavily colonized IVD is more likely to have the device removed instead of waiting for signs and symptoms of CRBSI to develop. The diagnostic criteria of CRBSI are clearly defined in Table 2.

A difficulty in reviewing IVD-related bloodstream infections is the large variation in what is considered to be an “infected device or catheter” with much debate existing as to precisely what is a significant quantity of bacterial growth [83]. Counts or CFUs of micro-organisms can range from 5 CFUs to 1000 CFUs depending on the type of diagnostic method used [81, 83, 84].

2.4.2 Prevalence of CRBSI in the clinical area

The most dangerous form of IVD-related infection is CRBSI, which may be localized and restricted to the catheter skin site, or systemic, where micro-organisms invade the bloodstream causing generalized sepsis and potential multiple-organ failure. The majority of serious CRBSIs associated with IVDs are primarily used in the ICU [31]. The propensity of patients acquiring CRBSI in the ICU is multifactorial. Critically ill patients in the ICU are generally exposed to more medical devices and are more severely ill compared with patients hospitalised on other wards. The presence of other independent predictors of catheter infection such as the patients’ severity of illness, longer requirement for intravascular access, the number of IVDs *in situ*, multiple episodes for fluids and medication administration,

the usage of multi-lumen IVDs, the use of jugular and femoral insertion sites make them more susceptible to acquire CRBSI [8, 85-87].

Maki and colleagues [8] conducted a systematic review of 200 prospective studies that used appropriate criteria to determine the incidence of CRBSI in different IVDs. The risk estimates of IVD-related BSI from these studies were:

Catheter site	Risk per 1000 catheter days
Peripheral intravenous catheters	0.5 (95% CI, 0.2- 0.7)
Non medicated, non-tunnelled and non-cuffed CVCs	2.7 (95% CI, 2.6-2.9)
Non-medicated, tunnelled and non-cuffed CVCs	1.7 (95% CI, 1.2-2.3)
Cuffed and tunnelled CVCs	1.6 (95% CI 1.5-1.7)
Arterial Catheters	1.7 (95% CI, 1.2-2.3)
Pulmonary arterial catheters	3.7 (95% CI, 2.4-5.0)
Peripherally inserted central catheters	1.1 (95% CI, 0.9-1.3)
Peripherally inserted midline catheters	0.2 (95% CI, 0.0-0.5)

Adapted from Maki et al. [8] CVCs = central venous catheters

CRBSI occurrence was estimated to occur at a rate of 5.0 per 1000 catheter days in the ICU setting [24].

2.4.3 Methods of reporting CRBSI

CRBSI incidence is obtained from the research literature and surveillance reports from infection control organizations. Incidence is difficult to compare between these two groups because firstly, research data has been traditionally been presented as proportions, and surveillance data in rates [31]. Another limitation to comparing data is that even with the two types of literature available, definitions of CRBSI have not been consistent [67]. In research

literature, many studies have favoured clinical diagnosis over microbiological confirmation, and the reverse is also true for surveillance literature.

There is also no standardized method used in reporting results from these studies, with some choosing to present their incidence rates in raw percentages [34, 35, 53, 56, 88-91] and others expressing their incidence rates per 1000 catheter days [54, 92, 93]. Raw percentages or incidence rates per 1,000 catheter days, however, do not take into account varying IVD durations and therefore may produce misleading comparisons. Other differences, such as study designs, heterogeneity of patient populations, catheter indwelling times, terminology, and techniques for microbial analyses, also contributed to this lack of standardization in reporting results and hence complicate comparison of different studies [8, 34, 35, 53, 54, 56, 88-90, 92, 93]. Surveillance studies within a particular ICU and comparisons between different ICUs also tend to utilise calculation methods for incidence rates which are insensitive to the mix of diseases and their severity and to the duration the IVDs remain *in situ*.

The reporting of colonisation and CRBSI rates is usually accomplished as raw percentages (e.g. 12% of all IVDs colonized) or as rates per 1,000 patient days (measured by Poisson or negative binomial regression). Neither of these methods is appropriate, as both assume that catheter colonization is a random event that suddenly occurs at a fixed level of probability. It is much more likely that colonization is governed by a growth pathway where the likelihood of the event increases exponentially.

In the studies reported by our team [60, 87, 94], the relative likelihood of microbial colonization was estimated by calculating hazard ratios (using Cox proportional hazards regression). This allows the effects of varying durations of IVD *in situ* times to be taken into account, although it does require IVD colonization at the time of catheter removal to be

defined rather inelegantly as a terminating event (as opposed to an incidental observation). This also avoids assuming that there is a linear association between likelihood of colonization and IVD *in situ* time, when it is more likely that the association will be some sort of exponential (if *in situ* time was used as an adjustment factor in a multivariate Poisson regression model).

Ideally, analysis would involve comparison in different patient / catheter groups of the exponential rate of microbial growth by non-linear regression, using multiple measurements of colonization whilst the IVDs are still *in situ*. However, the technology for such measurements does not currently exist.

2.4.4 How is CRBSI detected?

The current ‘gold standard’ markers for making a definitive diagnosis of CRBSI or IVD bloodstream infection derived from the CDC guidelines of 2002 requires the following three criteria to be present.

- 1) A positive catheter culture
- 2) A positive peripheral blood culture taken before IVD removal
- 3) The same micro-organism isolated from (1) & (2)

The presence of a positive catheter culture and an associated positive peripheral blood culture of the same biotype of a micro-organism allows for more accurate diagnosis of IVD-related bloodstream infection [31]. However, some studies have revealed that although it is often assumed that bacteria sharing the same biotype as being the same micro-organism, there was a 25% probability that the bacteria were actually different and quite distinguishable by DNA fingerprinting through pulsed-field gel electrophoresis [95, 96]. Moreover, the presence of a positive catheter culture and the absence of peripheral bacteraemia or a systemically proven infection may also represent either poor peripheral blood sampling, or even a transient fall in

peripheral blood load at the time of sampling [83]. Other studies have also revealed that blood culture contamination by skin micro-organisms is common, and that there is a low positive predictive value of positive blood cultures for micro-organisms, such as coagulase negative *Staphylococci* [97, 98].

The latest publication of clinical practice guidelines for the diagnosis of CRBSI available have made clearer recommendations for the diagnosis of CRBSI based on catheter culture and blood culture techniques, with recommendations to manage and treat CRBSI based on the micro-organism cultured [99]. It would be interesting if the CDC adopts some of these recommendations. As it stands, an array of diagnostic techniques to diagnose CRBSI exist.

2.4.5 Diagnostic Techniques

There are several diagnostic methods used to culture microbial content of catheters. However, there is no ‘gold standard’ method to which all techniques utilised for the diagnosis of CRBSI can be compared, and thus it is difficult to compare results from different studies using different diagnostic techniques to determine CRBSI. Diagnostic techniques can be divided into 2 classifications; (i) techniques which do not require removal of the IVD; and (ii) those that require IVD removal. A summary of these techniques, their different diagnostic criteria, accuracy, and disadvantages are presented in Table 3.

There are several problems and inconsistencies associated with the diagnostic techniques of determining CRBSI. Firstly, the effectiveness of each diagnostic technique can be scrutinised further by questioning if the detection of micro-organisms are only limited to the external surface (extra-luminal), the endo-luminal surface (intra-luminal), or both.

Table 3: A summary of the diagnostic techniques used to detect CRBSI in IVDs

Diagnostic criteria		Accuracy Sensitivity	Specificity	Disadvantages
Techniques without IVD removal				
Simultaneous quantitative blood cultures	Quantitative blood culture drawn through IVD yields CFU count five-fold higher or more than CFU count from simultaneously drawn blood from peripheral vein	93%	97–100%	Labour intensive, costly. Many variations in cut-off concentration of organisms between paired cultures. Not always able to obtain blood peripherally
Differential time to positivity	Blood culture drawn from IVD becomes positive ≥ 2 hours before simultaneously drawn blood culture from peripheral vein	89–90%	72–87%	Hard to interpret when patient is taking antibiotics through the IVD. Not always able to obtain blood peripherally.
IVD-drawn quantitative blood culture	Quantitative blood culture from IVD is ≥ 100 CFUs/mL	81–86%	85–96%	Cannot differentiate between CRBSI and high-grade bacteraemia
Acridine orange leucocyte cytosine test	Presence of any bacteria	87% (96% if followed by Gram stain)	94% (92% if followed by Gram stain)	Not widely tested or used. Conflicting data on its accuracy.
Endo-luminal brush	Quantitative culture with > 100 CFUs/mL	95%	84%	May induce bacteraemia, arrhythmia, & embolization. Need to culture all lumens in multi-lumen IVDs. Only culturing organisms embedded intra-luminally
Techniques requiring IVD removal				
Semi-quantitative IVD tip culture, roll plate	≥ 15 CFUs/mL from IVD tip	45–84%	85%	Unable to culture those micro-organisms embedded intra-luminally
Quantitative IVD culture: centrifugation, vortexing, sonication	≥ 103 CFUs from IVD tip	82–83%	89–97%	The cut-off point of $\geq 10^3$ CFUs versus $\geq 10^2$ CFUs is not well defined
Microscopy of stained IVD: Gram stain and acridine orange staining	Direct visualisation of the micro-organisms	84–100%	97–100%	Labour intensive, impractical
IVD = intravascular device, CFU(s) = colony forming unit(s), CRBSI = catheter-related bloodstream infection				Adapted from Raad, Hanna & Maki [25]

Secondly, different cut-off points for concentrations of micro-organisms between the paired blood cultures to positively predict the incidence of CRBSI exist [100-102]. This range from a 3-fold [102], 4-fold [101], 5-fold [100] difference in concentrations of micro-organisms drawn from the IVD and peripheral site, making comparison and interpretation of results difficult [103]. Besides, in 25-50% of cases of suspected CRBSI, it is often not possible to withdraw blood through these IVDs and the sensitivity of this technique is questioned [83].

Thirdly, there is a failure among the experts in this field to achieve consensus of which segment of the IVD needs to be cultured to accurately reflect an incidence of CRBSI. Culture of intravascular catheters traditionally involves culturing the distal 5cm of the IVD tip [54, 84, 104-106]. However, some studies have used the proximal subcutaneous segment of the IVD for culture and have found this method to have higher sensitivity and specificity especially in patients with long term CVCs (>30 days) [67, 81, 82, 107]. Raad and others however, dispute this practice and state that the culturing of the distal tips of IVDs is sufficiently useful to detect the presence of CRBSI [108, 109]. The recently published clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection also reiterate that the IVD tip rather than the subcutaneous segment of the IVD should be cultured [99]. It is important to note that this recommendation is derived from two randomised controlled trials whereby only six and seven cases of CRBSI respectively were used as the basis for comparison, hardly sufficient numbers to make those findings statistically robust [110, 111]. Moreover, both studies used the proximal subcutaneous segment for comparison to the tip [110, 111]. Our study (in Chapter 5) has focussed on culturing the entire length of the IVD which is embedded in the intravascular cavity of the blood vessel (the section of the IVD that sits in the blood vessel), thus culturing the proximal intravascular segment as opposed to the proximal subcutaneous segment of the IVD.

Traditionally, the IVD tip has been cultured and depending on which diagnostic technique is utilised, microbial yields in the form of CFUs are used to determine if the IVD is contaminated, colonized, or colonized beyond a pre-determined number of CFUs to indicate a diagnosis of CRBSI. This thesis raises a question mark concerning this current practice of culturing only the tip of the IVD as the proxy for determining if an IVD is contaminated or colonized or potentially likely to cause CRBSI, postulating that if microbial colonization originated and developed from the skin downwards, then it may be possible that the proximal intravascular segment of the IVD would become colonized earlier and have a heavier density of microbial colonization compared to the middle or distal segments of the IVD. The nature in which microbial biofilm develops on the surfaces of the IVD has not been extensively examined, and there is a possibility that microbial colonization on the proximal intravascular segment of any IVD may be releasing free-floating planktonic colonies of micro-organisms into the bloodstream with a potentiality to cause CRBSI, well before the same biofilm colonizes downwards towards the tip through time to effect a finding of microbial colonization at the IVD tip. Future research is required to determine whether such a finding may impact on the current diagnostic technique used to determine IVD colonization or CRBSI which rely heavily on culturing only the IVD tip.

Finally, the length of the catheter segment to be cultured needs to be standardized. In the original description of the Maki roll-plate technique, a range of 5cm-7cm of segments of intravascular catheters were sampled [80] whereas in other studies, only 3-4cm of the IVD tip was cultured [84, 107].

Other diagnostic techniques utilising extravascular sampling of the catheter hub [59, 61, 64, 68, 69, 112], skin entry site [113], and electron scanning microscopy [83] to detect microbial colonization to indicate the incidence of CRBSI have been deemed as unreliable, insensitive and non-predictive of CRBSI.

2.4.6 Prevention of CRBSI

Considerable progress has been made in the area of prevention of IVD-related bloodstream infection. Various novel preventive strategies have been developed because the pathogenesis of IVD bloodstream infections is amenable to interventions at many steps [3] These novel strategies can be categorised into three areas based on the level of evidence of (1) what works, (2) what probably works, and (3) what might work (Table 4).

Table 4: Categories of preventive strategies for IVD-related BSI

What works	What Probably works	What Might Work
1) Good hand hygiene	1) Antibiotic flushes & locks	1) Antimicrobial catheter hubs
2) Use of maximal sterile barriers during IVD insertion	2) Prevention of thrombus formation	2) Catheter securement devices
3) Use of Chlorhexidine 2% in alcohol 70% as agent for skin antisepsis	3) Antimicrobial-impregnated catheters in specific conditions	3) Active iontophoresis
4) Designated IVD therapy team		

Adapted from Cicalini et al., Hammarckjold et al., Sherertz et al., and Eggimann et al.[64, 105, 114, 115]

The “least novel” of preventive strategies against IVD-related bloodstream infections, are basic infection control practices such as good hand-washing, use of sterile gown, gloves and drapes during IVD insertion, using appropriate skin disinfectant, removing the IVD when no longer required, and avoiding using the femoral site for IVD are measures which effectively work [3, 7, 87, 105, 116-118].

The next section which has generated numerous randomised and efficacy trials in the past 3 decades contain novel technological strategies that would probably work. Antibiotic locks and antibiotic-impregnated IVD have emerged as a potentially valuable adjunct to the prevention of IVD-related bloodstream infection, however their efficacy is questionable given that they only remain effective against certain micro-organisms when used in specific situations [52]. Numerous clinical trials have been conducted to evaluate the preventive

efficacy of anti-microbial and antibiotic-coated IVD, using several combinations of antibiotics, such as minocycline [119-121], silver zeolite [122], silver sulfadiazine [75, 123-125], vancomycin [3, 126], rifampin [119-121], and chlorhexidine [75, 104, 123, 125] each presenting with supposedly efficacies.

Anti-coagulants such as heparin and enoxaparin have also been used as agents to prevent thrombus formation, which in turn prevents biofilm formation in IVDs. There have also been studies and trials introducing the use of antibiotic locks and hubs for IVDs but the effectiveness of these interventions are still unproven [68, 127].

In the last 20 years, extensive literature on how to prevent CRBSI has been published, leading to recommendations on what is useful and must be done, to what is useless and potentially ineffective and should be avoided [31, 128]. However, few studies have been conducted on ACs colonization rates and their associated potentiality of causing CRBSI. The limited focus on ACs is due to the relatively short duration ACs are left *in situ*, (usually 1-2 days duration) giving the false assumption, and somewhat accepted notion that ACs have a low infection risk. The latter ideology is also reinforced by the CDC guidelines which classify ACs as having “low infection rates, rarely associated with bloodstream infection”[31]. Given the lack of data about ACs and colonization rates, the need arose to determine if there was a difference in colonization rates between ACs & CVCs which were concurrently managed in a similar cohort of patients. The details of such a study undertaken as part of this doctoral study are presented in the following chapter.

These chapters have been removed for
copyright or proprietary reasons.

CHAPTER 6

Study 3: Intravascular Devices: A Survey of Clinical Practices

Evidence-based practice in healthcare is perceived as a process of inducting evidence arising from research into clinical decision making with the main emphasis of “doing the right things right” [154, 155]. It supports healthcare professionals in their decision making to eliminate ineffective, inappropriate, and potentially dangerous practices; improving clinical practice, health service management and patients’ choice [155, 156].

Practice guidelines and institutional infection control protocols provide a reference point for nurses involved with the care and management of IVDs to implement best practice. However, little is known about how closely nurses adhered to the guidelines and protocols when caring and managing IVDs, and if any variations in practice contributes to increased microbial colonization in IVDs. This final study seeks to determine the degree of concordance of current nursing practice to evidence-based practice guidelines, as a proxy for actual adherence to protocols, and how partial or non-adherence to protocols may impact on IVD colonization.

The study’s information sheet, consent form, questionnaire and answer template will be found in the Appendix section of this thesis.

Statement of contribution:

I was responsible for the study design, data collection, statistical analysis, interpretation and writing of this paper with consultations with Assoc Prof Rosalind Bull, Dr Robertson, and Dr Marianne Watts.

Footnote: The material in this chapter has been prepared for manuscript submission as “Intravascular Devices: A Survey of Clinical Practices” in Journal of Advanced Nursing.

ABSTRACT

Objective: This study explores current care and management of intravascular devices (IVDs) by registered nurses (RNs) in a regional hospital to determine the degree of concordance with evidence-based practice guide IVDs are indispensable for the management of critically-ill patients, but carry an associated risk of catheter-related bloodstream infection (CRBSI) increasing morbidity, mortality and health care costs. CDC Guidelines for the Prevention of Intravascular Catheter-Related Infections and institutional infection control practices are available, but there may be variations in clinical protocols and practice preferences resulting in varying degrees of concordance.

Design: A questionnaire was developed using the CDC Guidelines and current institutional practice protocols as benchmarks. Responses were analysed for degrees of concordance with guidelines in different clinical areas.

Results: Overall median concordance ranged from 28.6% - 66.7%. There was variation in the care and management of IVDs between clinical areas, and nursing practice reflected only partial concordance with CDC guidelines. Variation was present amongst RNs selection of IVD dressing supplies and equipment, as well as the frequency of dressing changes. Also, the mode of information dissemination appeared to be inimical with the respondents' preferences, suggesting access to practice protocols and guidelines may need to be addressed.

Conclusion: Care and management of IVDs were varied despite the existence of protocols and guidelines. Access to such information needs to be tailored to the preferences of end-users in order to achieve optimum concordance.

Introduction

Intravascular devices (IVDs) are indispensable for the management of critically and chronically ill patients. They provide safe, reliable vascular access, continuous haemodynamic monitoring, and are used in both the hospital and outpatient setting [8, 148]. Unfortunately, many healthcare-acquired infections in severely ill patients are caused by these medical devices [38, 60, 157]. Cases of catheter-related bloodstream infections (CRBSI) occur 250,000 - 500,000 times annually in hospitals in the United States [1, 83], and over 3,000 times annually in Australian hospitals [22], resulting in extended lengths of hospitalisation [16, 27], increased healthcare costs [13-15], and higher morbidity and mortality (12% - 35%) [13, 16, 27].

IVDs are inserted by physicians or specially-trained nurses, whilst the post-insertion care and management of IVDs are predominantly nursing responsibilities [158]. As an evidence-based profession, nursing draws on such protocols as those of the Centers for Disease Control and Prevention (CDC). The CDC reviews the evidence for effective preventive measures against IVD-related infection and makes recommendations for best practice [20, 31]. The CDC's recommendations are drawn on to develop effective nursing practice protocols to promote patient safety and decrease preventable infections. The protocols cover a variety of related topics such as IVD site care, dressing regimes, frequency of changing of administration sets, disinfection of IVD ports, to specific guidelines for care and management of arterial catheters (ACs), central venous catheters (CVCs), and peripherally-inserted central catheters (PICCs)[20, 31]. These guidelines help to inform nursing practice and provide a framework of evidence to enable appropriate clinical decision-making.

This paper reports findings from a study that formed part of a research program investigating microbial colonization in intravascular devices concurrently-sited in patients in a 350-bed, Australian, regional, teaching hospital. This study arose from previous findings which

revealed variations in IVD colonization rates in the different clinical practice areas. Three major routes of IVD colonization (i.e. extra-luminal, intra-luminal, endogenous spread) are postulated to contribute to IVD colonization. As nursing care and management of IVDs are implicit to the risk of extra-luminal and/or intra-luminal routes of colonization, the present study focused on determining if any variations in practice exist. Little is known about how closely nurses adhere to CDC guidelines and institutional protocols when caring and managing IVDs.

The Study

Aim

The aim of the study was to determine the degree of concordance of current nursing practices involving the care and management of IVDs by registered nurses (RNs) with the CDC recommended guidelines.

Design

A prospective, cross-sectional, anonymous survey was conducted in a 350-bed Australian regional, teaching hospital, from January to March 2010.

Sample

All RNs (n=308) involved with the care and management of patients with IVDs were invited to participate, with representation from medical, surgical, rehabilitation wards and the intensive care unit. RNs on leave during the study period were excluded.

Questionnaire

A questionnaire was designed using the CDC Guidelines for the Prevention of Intravascular Catheter-Related Infections as a benchmark to determine to the degree of concordance of nurse responses with current nursing practice (Table 12). The questionnaire, comprising 26 multi-choice questions and 12 open-ended questions contained the following sections: Management of IVDs; Infection Control Measures; Environment; and Resources and Training

(Appendix 3). Questions were then grouped into the following categories to provide an indication of the RNs concordance with CDC protocols:

- 1) Selection of supplies when changing IVD dressings;
- 2) The frequency of IVD dressing changes;
- 3) The rationales for IVD dressing changes;
- 4) The management of IVDs (i.e. external components of the IVD);
- 5) General knowledge base concerning the care & management of IVDs;
- 6) Infection control awareness;
- 7) Educational resources and training.

Table 12: Comparison of questionnaire's Categorical Questions with Centers for Disease Control Guidelines

Infection Control Procedure	Centers for Disease Control Guidelines [20, 31]	Level of Evidence *
<u>Selection of dressing supplies for IVD dressing</u> (questions B4,B5,C3,C4)	<i>No specific CDC recommendations on dressing supplies to be used for IVD dressings</i>	<i>Unresolved issue</i>
<u>Frequency of IVD dressing change</u> (questions B5, B6, B7, C5, C6, B1)	VII. E. <i>“Change dressings at least weekly for adult and adolescent patients depending on the circumstances of the individual patient”</i>	<i>Category II</i>
<u>Indications for application of dressing to IVD site:</u>		
(i) routine dressing change (question B5)	VII. A. <i>“Use either sterile gauze or sterile, transparent semi-permeable dressing to cover the catheter site”</i>	<i>Category 1A</i>
(ii) loose dressing, or IVD site bleeding or oozing	VII. D. <i>“Replace catheter-site dressing if the dressing becomes damp, loosened, or visibly soiled”</i>	<i>Category 1B</i>
(ii) diaphoretic patient (question B8)	VII. C. <i>“If the patient is diaphoretic, or if the site is bleeding or oozing, a gauze dressing is preferable to a transparent, semi-permeable dressing”</i>	<i>Category II</i>
<u>Management of external components of the IVD</u>		
(i) administration sets, transducers replacement (question C7 (i-iv))	IX. A.1. <i>“Replace administration sets, including secondary sets and add-on devices, no more frequently than at 72-hour intervals, unless catheter-related infection is suspected or documented”</i>	<i>Category 1A</i>
(ii) positive-pressure valves (questions B9, B10)	IX. B.1. <i>“Change needleless components at least as frequently as the administration set”</i>	<i>Category II</i>
(iii) caps (questions B10, B11.)	IX. B.2. <i>“Change caps no more frequently than every 72 hours or according to manufacturer’s recommendations”</i>	<i>Category II</i>
(iv) disinfecting of access ports (question B15)	IX. B.4. <i>“Minimize contamination risk by wiping the access port with an appropriate antiseptic and accessing the port only with sterile devices”</i>	<i>Category 1B</i>
<u>Rationales for more frequent IVD dressing changes</u> (questions B1, B3, B7)	VIII. G. <i>“Replace any short-term CVC if purulence is observed at the insertion site, which indicates infection”</i>	<i>Category 1B</i>
<u>Knowledge of replacement of IVDs based on time-in situ</u> (questions B2, B17, B18,B19)	VIII. F. <i>“Use clinical judgement to determine when to replace a catheter that could be a source of infection (e.g.: do not routinely replace catheters in patients whose only indication of infection is fever)”</i>	<i>Category II</i>
<u>General knowledge base concerning the care and management of IVDs</u> (questions B1,D1.D3,D4)		
(i) maximal sterile barrier precautions (questions D1,D3)	I.A. <i>“Educate health-care workers regarding the indications for intravascular catheter use, proper procedures for the insertion and maintenance of intravascular catheters, and appropriate infection-control measures to prevent intravascular catheter-related infections”</i>	<i>Category 1A</i>
(ii) hand hygiene (questions C1,C2)	III. A. <i>Observe proper hand-hygiene procedures either by washing hands with conventional antiseptic-containing soap and water or with waterless alcohol-based gels or foams. Observe hand hygiene before and after palpating catheter insertion sites, as well as before and after inserting, replacing, accessing, repairing, or dressing an intravascular catheter</i>	<i>Category 1A</i>
(iii) Aseptic technique (question D2)	1.B. <i>“Assess knowledge of and adherence to guidelines periodically for all persons who insert and manage intravascular catheters</i>	<i>Category 1A</i>

*Level of Evidence: 1A, strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiological studies; 1B, strongly recommended for implementation and supported by some experimental clinical, or epidemiological studies, and a strong theoretical rationale; 1C, required by (U.S.) state or federal regulations, rules or standards; II, suggested for implementation and supported by suggestive clinical or epidemiological studies or theoretical rationale; Unresolved Issue, represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists; CDC, Centers for Disease Control; IVD, intravascular devices.

The internal construct validity of the questionnaire was reviewed initially by an RN-academic with expertise in wound care and infection control policies and a medical biostatistician with intensive care and public health experience to determine that the research questions reflected the phenomena of interest [159]. The questionnaire was pilot tested by clinical nurse educators (CNEs) (n=7) from each clinical area. A revised version of the questionnaire was then distributed to all RNs (n=308) who met the inclusion criteria.

A prescribed template of correct answers to all questions in the questionnaire was used to ascribe concordance scores to all responses received. The prescribed template of correct answers was based on a combination of the CDC recommended guidelines and institutional protocols (in instances whereby the CDC guidelines do not provide any suggestions). The prescribed template of correct answers and concordance scores was created by the researcher and approved by an RN-academic with expertise in wound care and infection control policies. All questionnaire responses were compared to the prescribe template of answers for accuracy.

Responses were analysed and ascribed concordance scores, which took the form of a rank order scale of either 'total concordance', 'partial concordance - high partial', 'partial concordance - low partial', or 'non-concordance'. A response that contained all the correct answers or components required of that question will be ascribed 'total concordance'. Partial answers with more than 50% but less than 100% accuracy in answer component will be ascribed a 'high partial concordance', while those with less than 50% but more than 25% accuracy will be accorded a 'low partial concordance'. Responses which contained less than 25% accuracy in answer component will be deemed as 'non concordant'. Any response whereby the rank order scale of concordance was in doubt was further verified by the RN-academic to achieve consensus in awarding the appropriate concordance score, thereby eliminating bias from the researcher. Correct responses were coded with a for total

concordance, high partial concordance, moderate partial concordance, low partial concordance, and non concordance.(Appendix 3)

Data Collection

Information sessions (n= 26) were conducted for RNs in all clinical areas at different times to accommodate all shift-working staff. Distribution of questionnaires was varied in the clinical areas and the final mode of distribution was determined after close consultation with the respective ward's CNE. Completed questionnaires were returned to the researcher via institutional internal mail. No subject identifier information was collected.

Ethical And Etiquette Considerations

Human Research Ethics Committee approval (H0010857) was obtained and confidentiality of individual participants was protected. Questionnaires were administered without collection of subject identifiers. Permission to conduct the study and administer the questionnaires was gained from the Directors of Nursing of the hospital and nurse unit managers of the different clinical areas.

Data Management & Statistical Analysis

Predictor variables

Demographic data of respondents and their clinical areas was obtained. The hierarchical rank of respondent, employment status (part-time or full-time), clinical area, institution or agency staff, numbers of years in nursing, whether trained locally or elsewhere, and if possessed post-registration qualifications were recorded.

Outcome measures

The degree of concordance was determined based on classification of the responses received. All responses to questions were then ascribed concordance scores. The association of degree of concordance with predictor variables for each component of IVD management protocols was then established using ordinal logistic regression (a non-parametric equivalent of

multivariate analysis of variance) expressed as odds ratios (OR) and 95% confidence intervals (95% CI) for nominal categories or odds ratios for trends for continuous values or rank-order categories, corrected where appropriate for repeated measures and for multiple comparisons by the Holm method. Backward stepwise ordinal logistic regression was used to select multivariate models of association of predictor variables (P for removal = 0.2, P for entry = 0.12). Analyses were performed using *Stata IC 10.1™ for Windows™* (StataCorp, College Station, Texas, USA).

Results

Sample

202 (65.6%) out of 308 distributed questionnaires were returned. There was a marginally higher response from ICU nurses (OR, 2.48; 95% CI, 1.05 - 5.83; $p = 0.23$; overall Fisher's exact test for distribution $p = 0.05$) Table 13.

Table 13: Questionnaire response rates from respective clinical areas

Clinical Area	Responses	Potential	Raw percentage
Surgical Ward ¹	28	45	62.2%
Surgical Ward ²	29	46	63.0%
Medical Ward ³	27	39	69.2%
Medical Ward ⁴	27	45	60.0%
Medical Ward ⁵	21	42	50.0%
Rehabilitation Ward ⁶	17	25	68.0%
Intensive Care Unit ⁷	53	66	80.3%

¹ General surgical ward with specialization in colorectal, abdominal, and urological surgery.

² General surgical ward with specialization in orthopaedics, maxilla-facial, ear, nose, throat (ENT), and gynaecological surgery.

³ General medical ward with specialization in renal medicine and endocrinology.

⁴ General medical ward with specialization in oncology, haematology and immunology.

⁵ General medical ward with specialization in cardiology and neurology.

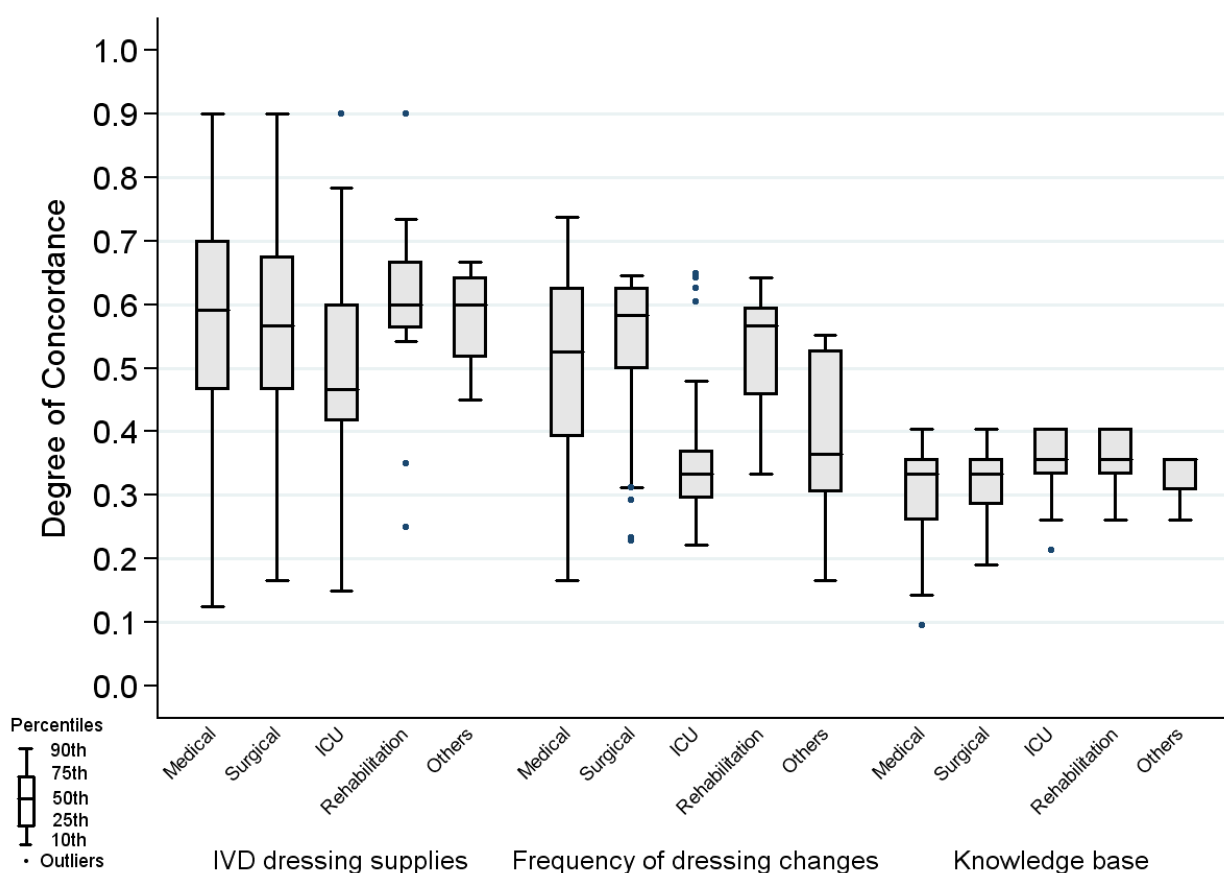
⁶ Rehabilitation ward containing a mixture of post-surgical and medical patients.

⁷ Intensive care unit which treats all forms of acute illnesses with the exception of cardiothoracic-surgical and neurosurgical cases.

Category 1: Selection of supplies when changing of IVD dressings

Median overall concordance was 56.7% (inter-quartile range (IQR), 45.8% - 66.7%). Higher ranked RNs tended to be more concordant in their selection of dressing equipment for an IVD dressing change (OR for trend, 1.28; 95% CI, 0.90 - 1.82; $p = 0.17$); as were RNs who were working fulltime (OR, 1.30; 95% CI, 0.99 - 1.70; $p = 0.06$) when compared with their part-time colleagues. ICU RNs were more concordant in replacing or applying an alternative IVD dressing in a diaphoretic patient or in a scenario where the IVD site was bleeding or oozing (OR, 2.39; 95% CI, 1.05 - 5.46; $p = 0.04$); compared to general surgical ward RNs (OR, 0.54; 95% CI, 0.28 - 1.03; $p = 0.06$); however, ICU RNs were less concordant with selection of IVD dressing equipment (OR, 0.40; 95% CI, 0.23 - 0.71; $p = 0.002$), and routine IVD dressing change protocols (OR, 0.10; 95% CI, 0.05 - 0.21; $p < 0.001$) compared to RNs in other clinical areas. ICU RNs had lower overall concordance (OR, 0.39; 95% CI, 0.2 - 0.77; $p = 0.006$) in this category when compared to RNs from all other clinical areas (Figure 10). There was also a large variation in the degree of concordance expressed by the different respondents from the wards where the IVDs tend to be used (ICU, medical, and surgical wards) in response to the questionnaire. Figure 10 illustrates overall concordance percentiles of RNs from the different clinical areas with reference to the categories of (i) Selection of supplies when changing of IVD dressings; (ii) Frequency of IVD dressing changes; and (iii) General knowledge base concerning the care & management of IVDs.

Figure 10: Box plot showing overall concordance to questions asked in categories 1, 2 & 5



Category 2: Frequency of IVD dressing changes

Median overall concordance was 48.8% (IQR, 36.9% - 59.4%). Rehabilitation ward RNs were most concordant to the recommended protocol of weekly dressing changes for CVCs (OR, 1.51; 95% CI, 1.00 - 2.29; $p = 0.05$); and PICCs (OR, 1.39; 95% CI, 0.95 - 2.04; $p = 0.09$). RNs who possessed higher post-registration nursing qualifications also tended to be more concordant to the recommended protocol of weekly CVC dressing changes (OR, 0.77; 95% CI, 0.57 - 1.03; $p = 0.08$) when compared to those nurses with basic nursing qualifications, as were RNs who have had a longer service in nursing than those who were not for CVCs (OR for trend, 0.75; 95% CI, 0.55 - 1.01; $p = 0.06$), and PICCs (OR for trend, 0.75; 95% CI, 0.54 - 1.04; $p = 0.09$). ICU RNs were the least concordant to the recommended frequency of weekly dressing to CVCs (OR, 0.15; 95% CI, 0.06 - 0.38; $p < 0.001$), PICCs

(OR, 0.11; 95% CI, 0.04 - 0.32; $p < 0.001$) and ACs (95.83% (46 out of $n=48$) preferring to change their AC dressings every 4 days or more frequently).

Respondents were asked to select as many clinical scenarios which they deemed appropriate to necessitate an IVD dressing change out of the recommended protocol of weekly change. The scenarios were: (i) when the IVD site is oozing with blood underneath the dressing; (ii) when the IVD site is red and inflamed; (iii) when the transparent dressing of the IVD site is partially lifting; and (iv) when the patient requests the nurse to do so. General surgical ward RNs were more concordant to protocol concerning weekly frequency of changing IVD dressings (OR, 3.79; 95% CI, 1.42 - 10.11; $p = 0.008$), when the IVD site was oozing, looked red or inflamed, and had blood underneath the transparent dressing, compared to their colleagues from other clinical areas. RNs who did their pre-registration preparation locally (OR, 0.61; 95% CI, 0.39 - 0.95; $p = 0.03$) also tended to be more concordant to changing IVD dressings more frequently under these clinical scenarios than those who trained elsewhere. ICU RNs scored the least concordance in this question as they tended to change the IVD dressing more frequently under all of these clinical scenarios (OR, 0.11; 95% CI, 0.008 - 1.51; $p = 0.099$), resulting in a poor overall concordance score (OR, 0.10; 95% CI, 0.04 - 0.22; $p < 0.001$) in this category when compared to RNs from all other clinical areas (Figure 10)

Category 3: The rationales or reasons for IVD dressing changes

Median overall concordance was 50% (IQR, 41.7% - 58.3%). There are many reasons why nurses change IVD dressings. Respondents indicated observing for the following characteristics during routine IVD site inspection:

- a) **Site:** If there was any inflammation, redness, swelling, oozing, or bleeding at the IVD site

- b) **Line:** Ensuring patency and functionality of the IVD, to inspect if the IVD was dislodged, or if there was leaking around the skin site of IVD insertion.
- c) **Dressing:** Inspecting the site for IVD dressing integrity, condition of dressing, etc.
- d) **Other:** Other reasons for IVD site inspection such as, as per protocol or to find out the date and time of the last dressing change, etc.

ICU RNs (OR, 3.98; 95% CI, 1.94 - 8.14; $p < 0.001$ and OR, 2.00; 95% CI, 1.08 - 3.73; $p = 0.03$) provided the most concordant answers to these 2 questions, followed by higher ranked RNs (OR for trend, 1.25; 95% CI, 0.95 - 1.66; $p = 0.11$ and OR for trend, 1.43; 95% CI, 1.04 - 1.98; $p = 0.03$) and those who have had a longer service in nursing (OR for trend, 0.76; 95% CI, 0.54 - 1.07; $p = 0.11$ and OR for trend, 0.78; 95% CI, 0.58 - 1.04; $p = 0.09$). 96% (n=199) of respondents indicated that an IVD site which is red and inflamed, or a CVC or PICC which has been *in situ* for more than 7 days (83.4%) may be potential indicators of infection. 34.7% of respondents attributed a spike in body temperature above 38°C and an IVD site which had an exudate or was leaking (33.7%) as predictors of infection. Medical and surgical ward RNs (OR, 2.55; 95% CI, 1.30 - 5.00; $p = 0.006$) and ICU RNs (OR, 2.25; 95% CI, 1.18 - 4.32; $p = 0.014$) regarded routine IVD dressing changes as a lesser priority of routine nursing care in instances where they became busy with other nursing care, when compared to nursing staff from the medical or rehabilitation wards. ICU RNs (OR, 4.14; 95% CI, 1.91 - 8.96; $p < 0.001$) had better overall concordance in this category than their colleagues from other clinical areas.

Category 4: The management of IVDs

Median overall concordance was 48.9% (IQR, 43% - 53.1%). Higher ranked RNs (OR for trend, 2.13; 95% CI, 1.06 - 4.29; $p = 0.03$) were more concordant in applying positive-pressure valves on the ends of the unused lumens of CVCs and PICCs, and replacing caps, valves and

bungs on the ends of the unused lumens of CVCs and PICCs on a weekly basis (OR, 1.36; 95% CI, 1.00 - 1.85; $p = 0.05$). ICU RNs (OR, 3.44; 95% CI, 0.90 - 13.12; $p = 0.07$) were more concordant in flushing the unused lumens of their patients' CVCs and PICCs regularly compared to their rehabilitation ward nursing colleagues (OR, 1.37; 95% CI, 0.26 - 7.18; $p = 0.29$) and general surgical ward RNs (OR, 0.58; 95% CI, 0.21 - 1.61; $p = 0.29$). However, the majority of respondents were flushing the unused lumens of CVCs and PICCs at least once a shift. 92.1% of RNs decontaminated the hub or port of an IVD with rigorous friction rubbing with an alcohol swab for 60 seconds before connecting to an administration set, with 6.3% partially concordant and 1.6% non-concordant. Concordance was similar for all RNs in this category of the questionnaire.

Category 5: General knowledge base concerning the care & management of IVDs

Median overall concordance was 35.7% (IQR, 28.6% - 35.7%). Full-time-employed RNs (OR, 1.36; 95% CI, 0.94 - 1.97; $p = 0.10$) had more knowledge of when a CVC should be replaced when compared to RNs who worked part-time, as were RNs who were more qualified and possessed post-registration nursing qualifications (OR, 0.76; 95% CI, 0.55 - 1.05; $p = 0.10$), and those who have had a longer service in nursing (OR for trend, 0.63; 95% CI, 0.42 - 0.97; $p = 0.03$). RNs working in general surgical wards (OR, 1.68; 95% CI, 0.88 - 3.25; $p = 0.12$) were more knowledgeable on how long a PICC could remain *in situ* in a patient. ICU RNs who possessed post-registration nursing qualifications (OR, 1.79; 95% CI, 0.93 - 3.46; $p = 0.08$) gave more concordant answers to how long an AC should remain *in situ* when compared to their less credentialed colleagues. Highest overall concordance scores for this category were attained by rehabilitation ward RNs (OR, 3.48; 95% CI, 1.23 - 9.82; $p = 0.02$) and ICU RNs (OR, 2.41; 95% CI, 1.23 - 4.70; $p = 0.01$) demonstrated by the higher median (and other percentiles) when compared to RNs from other clinical areas (Figure 10).

Category 6: Infection control awareness

Median overall concordance was 49.2% (IQR, 43.6% - 52.5%). General surgical ward RNs (OR, 0.51; 95% CI, 0.24 - 1.09; $p = 0.09$), Ward F RNs (OR, 0.37; 95% CI, 0.12 - 1.12; $p = 0.08$) and ICU RNs (OR, 0.36; 95% CI, 0.16 - 0.76; $p = 0.01$) identified “effective vigilant hand-washing” as the single most effective measure to reduce IVD-related infections in their clinical areas. 88.8% of concordant respondents understood that “maximal barrier precautions” referred to “the use of sterile instruments, sterile drapes, gown, gloves and mask during CVC or PICC insertion procedures; with surgical ward RNs (OR, 0.49; 95% CI, 0.18 - 1.35; $p = 0.17$) and ICU RNs (OR, 0.16; 95% CI, 0.03 - 0.80; $p = 0.025$) providing more concordant responses compared to other nursing staff. Nursing pool RNs (OR, 4.97; 95% CI, 0.75 - 32.85; $p = 0.10$) provided the highest concordance responses for understanding the term “strict asepsis” compared to other nurses. 82% of RNs utilised effective hand-washing techniques in their respective clinical areas as recommended by institutional infection control protocols and CDC recommended guidelines, with general surgical ward RNs (OR, 2.11; 95% CI, 0.82 - 5.40; $p = 0.12$) and ICU RNs (OR, 1.86; 95% CI, 0.77 - 4.55; $p = 0.17$) attaining highest concordance than the other RNs. ICU RNs (OR, 7.07; 95% CI, 1.69 - 29.65; $p = 0.007$) and RNs who were more highly ranked (OR for trend, 1.70; 95% CI, 1.11 - 2.57; $p = 0.013$) were more likely to be concordant in selecting the appropriate cleaning and disinfecting solutions. There was uniformly high overall concordance among all clinical areas in this category.

Category 7: Resources and training

46.8% of respondents identified a unit’s protocol folder as their first preference of information, with 30.7% of respondents indicating this as their second option. The hospital’s intranet website was the first preference for 34.2% of respondents and 18.4% the second preference. RNs preferred the hospital’s guideline folder (45.7%) rather than its intranet website (18.4%) as their second preference for seeking information about the care and management of IVDs

(Table 14). Nurses with a longer service in nursing appeared to be more likely to consult other staff (OR for trend, 2.94; 95% CI, 0.74 - 11.6; $p = 0.13$), and less likely to access the intranet (OR for trend, 0.69; 95% CI, 0.41 - 1.35; $p = 0.14$).

Table 14: Respondents preferences of where to seek information

Answers	% 1st preferences (n/total)	% 2nd preferences (n/total)	% 3rd preferences (n/total)
unit's protocol folder	46.8 (87/186)	30.6 (57/186)	17.2 (32/186)
hospital's guideline folder	15.1 (28/186)	45.7 (85/186)	31.7 (59/186)
hospital's intranet website	34.2 (65/190)	18.4 (35/190)	35.3 (67/190)
general internet search engine	1.1 (2/181)	2.2 (4/181)	9.9 (18/181)
other sources	28.8 (15/52)	9.6 (5/52)	15.4 (8/52)

The majority of respondents indicated they would first approach their clinical nurse educator for advice (OR, 11.2; 95% CI, 7.02 - 17.86; $p < 0.001$), followed by asking a more senior or experienced ward RN (OR, 2.51; 95% CI, 1.75 - 3.60; $p < 0.001$), or by calling another clinical area (OR, 1.36; 95% CI, 0.97 - 1.91; $p = 0.07$). Most respondents were less likely to consult the infection control nurse (OR, 0.61; 95% CI, 0.40 - 0.93; $p = 0.02$) or other less senior or less-experienced ward staff (OR, 0.73; 95% CI, 0.48 - 1.12; $p = 0.16$). Nursing staff who have had a longer service in nursing tended to prefer using a document folder as an information resource, with a lesser preference for using a general internet search engine (OR, 0.74; 95% CI, 0.48 - 1.13; $p = 0.16$) or the hospital's intranet site (OR, 0.54; 95% CI, 0.33 - 0.87; $p = 0.01$) or consulting a specialist nurse clinician (OR, 0.47; 95% CI, 0.3 - 0.75; $p = 0.001$). On the other hand, higher ranked RNs preferred to access the hospital's intranet (OR for trend, 1.61; 95% CI, 0.99 - 2.63; $p = 0.06$) or a general internet search engine (OR for trend, 1.28; 95% CI, 0.92 - 1.78; $p = 0.15$) to source information. Surgical ward RNs preferred to use the intranet (OR 3.04; 95% CI 0.94 - 9.85; $p = 0.06$), a general internet search engine (OR 2.38; 95% CI 0.87 - 6.50; $p = 0.09$) or consult another health professional (OR, 2.2;

95% CI, 0.75 - 6.46; $p = 0.15$) than to refer to a document folder containing standards, guidelines and protocols of clinical practice. Medical ward RNs on the other hand preferred using a document folder rather than seeking information from the hospital's intranet site (OR, 0.3; 95% CI, 0.13 - 0.67; $p = 0.003$). ICU RNs also had a strong preference to access a document folder rather than a general internet search engine (OR, 0.71; 95% CI, 0.26 - 1.96; $p = 0.51$) or the hospital's intranet website (OR, 0.41; 95% CI, 0.12 - 1.35; $p = 0.14$). Rehabilitation ward staff had equal preferences to all sources of information whereas nursing pool staff preferred asking another health professional (OR, 16.4; 95% CI, 1.02 - 265; $p = 0.05$) and accessing a document folder. 77.7% (153 of 197) of respondents indicated that an education session on the care and management of IVDs would be of much benefit, with a further 20.3% (40 of 197) indicating such a session to be of some benefit. 52.3% (103 of 197) of respondents indicated that they would attend such an education session at their own time whereas 30.0% (59 of 197) preferred the session to be part of a paid study day.

Discussion

Limitations

The sample of respondents was limited to one regional hospital and therefore cannot be representative of all other hospitals in Australia or worldwide. However, it did include participants from different clinical areas within this hospital and the results may be transferable to similar settings. Previous findings revealed variations in IVD colonization rates in the different clinical practice areas, however it was not possible to determine whether those differences were due to patient-related factors (e.g. severity of disease, immune-compromised, or use of antibiotics) or staff-related factors (e.g. different sterile techniques, or different IVD insertion practices).

The prescribed template of correct answers was based on a combination of the CDC recommended guidelines (which represent best practice) and institutional protocols (in instances whereby the CDC guidelines do not provide any suggestions). Subjective responses whereby the rank order scale of concordance could not be applied were approved by the RN-academic and the researcher to achieve consensus in awarding the appropriate concordance score, thereby eliminating any bias in the study. It is implied by the construction of the questionnaire analysis coding that “non-concordance” is equivalent to “less satisfactory”: there is the possibility that some responses from some nurses may represent more satisfactory responses than the protocol-mandated responses. Those differences of opinion can only be arbitrated by randomised controlled trials or equivalent research findings beyond the scope of this study.

Discussion of results

This study sought to determine whether there were variations in the degree of concordance of current clinical practice to practice guidelines in the care and management of IVDs rendered by nurses in the different clinical areas. There remained the possibility that some of the lack of concordance with protocols is the result of RNs adopting alternative clinical practices which may decrease infection risk, suggesting that the CDC protocols themselves may not be optimal: however, in the absence of randomised controlled trials of these variations it is unclear how the nurses would know whether their alternative management would actually decrease infection risk. This study has revealed that RNs from this hospital gave responses that suggest less than full adherence to the CDC guidelines and variations in the nursing care and management of IVDs showed degrees of partial or non-concordance to the guidelines and protocols.

Category 1: Selection of supplies when changing of IVD dressings

Selection of dressing supplies for an IVD dressing change diverged from protocols. There appears to be no standardised list of equipment that RNs utilise to change an IVD dressing. This area needs to be investigated, because the current CDC guidelines do not specifically itemise what dressing supplies, solutions, or dressing technique should be used, and RNs are left to interpret these guidelines based on clinical judgement and nursing experience [31]. For example, in this study, normal saline was the preferred IVD-site cleansing solution over sterile water, while some respondents used only chlorhexidine in alcohol 70% during IVD dressing changes. The absence of an IVD dressing protocol in some clinical areas and the apparent lack of awareness of the interaction between cleansing and antiseptic solutions might have contributed to a lower overall concordance score in responses in this category. This finding is disconcerting because inappropriate cleansing during an IVD dressing change may contribute to higher colonization rate in IVDs [64, 137, 160-162]. Prompted by this study, a “central venous access device (CVAP) dressing standard operating procedure” booklet was produced by one of the hospital’s CNE to assist RNs with general queries about the selection of supplies for the changing of IVD dressings.

Category 2: Frequency of IVD dressing changes

RNs in ICU were changing IVDs dressings more frequently than recommended. It is arguable that the broad nature of these CDC recommendations may be easily misinterpreted as recommending that IVD dressings be changed more frequently than the maximum 7 days, and that RNs could change the IVD dressing more frequently based on the scenarios cited in CDC recommendation VII.C and D. The CDC does not recommend any set time interval for routine IVD dressing changes, as there has been no published evaluation of the inherent efficacy of changing IVD dressings more frequently than the 7-day maximum limit recommended [163-165]. It is not known if more frequent IVD dressing changes may have an effect on

colonization rates in these devices. Frequent IVD dressing changes (< 7days) may be a waste of time and resources. However, until a randomised controlled trial supports a more finite timeframe for IVD dressing changes, current practice will be determined by clinical nursing judgements, reasoning that frequent IVD dressing changes equate to less local infection at the IVD site. Also unless the hospital or wider health system has a mechanism for effectively judging and communicating the value of different competing resource use to departmental staff making individual resource use decisions, those staff have no way of deciding reliably how to validly allocate resources in their own practice. It might be hypothesised that avoiding frequent IVD dressing changes may assist appropriate resource allocation, but in the absence of randomised controlled trial meta-analysis data on the one hand, and clear guidance on known-value resource allocation policies from the wider system on the other hand, this remains difficult to determine.

Category 3: The rationales or reasons for IVD dressing changes

Respondents in this study had a sound understanding of the rationales behind the care and management of IVDs, an awareness of infection control practices, and were capable of exercising clinical judgements based on IVD site infection indicators. Most respondents indicated that they would be concerned about the patients' potential susceptibility to IVD-related infection if their ACs and CVCs remained *in situ* for longer than 7 days, and if the PICCs were *in situ* for longer than 6 months [32, 53, 128]. The CDC guidelines however do not stipulate any timeframe for how long ACs, CVCs or PICCs should remain *in situ*.

Category 4: The management of IVDs

This category focused on regular flushing and application of positive-pressure bungs to unused lumens of the IVDs, and the decontamination of the port of an IVD [59, 68, 69, 71, 119, 166].

The institution's infection control protocols and CDC guidelines were clear and specific in this instance and there was uniform concordance.

Category 5: General knowledge base concerning the care & management of IVDs

Respondents who were more concordant in this category tended to work in clinical areas which nursed higher volume of patients with IVDs, and were predominantly full-timed staff with post-registration nursing qualifications. This suggested a trend that respondents with more frequent interactions with IVDs in clinical practice tended to inquire into their practice to obtain the necessary information and skills to effectively care and manage a patient with an IVD.

Category 6: Infection control awareness

While a high percentage of RN respondents (82%) demonstrated that they were vigilant with effective hand-washing techniques, and 88% understood the meaning of “maximal barrier precautions”, the study highlighted that a small proportion of RNs were not vigilant with their hand-washing techniques or their abilities to maintain asepsis. The consequences in terms of infection and potential higher colonization rates in IVDs are far reaching. This study suggests that these RNs should be given further education and training in these essential areas to reduce these risks and an online learning package adapted from Hand Hygiene Australia was incorporated into the institution's policy to ensure all employees were accredited annually. An infection control program using education and performance feedback, and regular surveillance may result in significant reductions in rates of colonization and CRBSI [16, 167].

Category 7: Resources and training

The provision of education in prevention strategies is critical in reducing the risk of CRBSI, improving patient safety, and promoting quality health care [27, 31]. The respondents' healthcare institution has in recent times advocated professional development activities

through the usage of information technology media. However, RNs tended to prefer using the hospital guidelines folder rather than electronic sources to seek information about the care and management of IVDs. Our study has identified that the mode of instruction and information dissemination selected by the institution may not always match the preference of the target group, therefore compromising their access to available information. Users' preferences are relevant for effective implementation of information dissemination as it not only incorporates the users' needs but also enhances users' acceptance and generates a sense of ownership of responsibility for professional development [168]. On the other hand, health services are primarily processors of information, identifying patient needs and matching those to optimum knowledge. There may be opportunities in the future for use of information technology to deliver recommendations at the bedside at the time of making decisions and undertaking procedures. It would be useful to understand the motivations and decision-making of staff whilst designing this technology to promote its user-friendliness.

Another trend to emerge from this study was that RNs who had been nursing longer tended to seek information by consulting a more experienced colleague rather than accessing the intranet. This may be due to a lack of computer experience, but could also be behaviour related. Studies in nurses' clinical decision-making behaviour have found RNs rating experiential knowledge more useful than educational resources in text or electronic media [169, 170]. The reason for this phenomenon could arguably be a direct consequence of nursing being a profession that is more social and communication-oriented than technology-oriented [171, 172]. This highlights another area for potential staff development and training in the use of electronic media. Addressing this area may reduce the variance in clinical practices, thereby improving overall concordance to the CDC guidelines and adapted institution protocols governing the care and management of IVDs in this institution. This needs to be accompanied by ongoing effectiveness research.

Conclusion

The study revealed discrepancies in concordance between the CDC guidelines and current clinical practice, but we are only able to postulate the cause of these discrepancies. The CDC guidelines are to date the most useful evidence-based document available for IVD care, but in some cases recommendations cannot be given because of inadequate or conflicting research. However, it is not unreasonable to expect that the CDC guidelines should be reflected in clinical practice. Nurses have in recent times tried to address the knowledge-practice gap by cultivating an evidence-based practice culture. However, unless the evidence is made more accessible to the end-users' preferences, or if nurses were willing to keep up with the times by being more information technologically oriented and that hospital management should more effectively facilitate this new orientation, this knowledge-practice gap may continue to exist. Knowledge of the protocols guiding the nursing care and management of IVDs are essential to minimise or prevent the various mechanisms of colonization of IVDs in the clinical area.

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Conflict of Interest

No conflict of interest has been declared by the authors.

Author contribution

DBCK, RB, IKR and AND were responsible for the study conception and design. DBCK performed data collection, data analysis and the drafting of the manuscript. RB, IKR and MW made critical revisions to the paper for important intellectual content. IKR provided statistical expertise. RB and IKR supervised the study.

Summary Statement

What is already known about this topic:

- Intravascular devices (IVDs) are indispensable for the management of critically and chronically ill patients in both the hospital setting and outpatient setting.
- Patients with IVDs have a potential risk of catheter-related infection, which increases their morbidity and mortality, as well as health care costs
- The Centers for Disease Control and Prevention (CDC) provide evidence-based practice guidelines for the management and care of IVDs
- Hospitals adapt the CDC guidelines in the implementation of infection control policies to prevent and minimise the risk of infection
- Nurses rely on evidence-based guidelines and protocols to direct nursing practice

What this paper adds

- A review of current nursing practice with regards to the care and management of IVDs in an Australian, regional hospital.
- Determines the degree of concordance of current nursing practice to evidence-based CDC practice guidelines.
- Recommendations for nursing practice, education and future research.

Implications for practice and/or policy

On the basis of this study, we recommend that:

1. Individual clinical nursing areas should undertake a review of their existing practice protocols with regards to the care and management of IVDs, with particular reference to the CDC guidelines. Our questionnaire may be a useful, quality audit tool for practice review.
2. Where partial or non-concordance to existing guidelines and protocols are evident, education of staff should be provided with emphasis on the CDC guidelines and institution's infection control protocols.
3. The use of evidence-based practice by RNs should be supported by regular review of the accessibility modes of educational resources available in the clinical area. The mode chosen to present such vital information should be evaluated against the end-users' preferences
4. An observational study of IVD care and management in the clinical areas may be useful in providing a more direct measure of the RN's infection control practices, with the goal of improving patient outcomes from the incidence of IVD colonization and CRBSI.

CHAPTER 7

Discussion

7.1 Introduction

This general discussion will demonstrate how this body of work developed in response to results obtained during the course of the research. Each research phase is discussed individually in sections 7.1.1 to 7.1.4 of this chapter. There may also be some additional comments of results and interpretation of each chapter that may not have been evident or deemed relevant at the time of initial publication, or that were precluded from inclusion due to word limitations imposed by the publishers.

7.1.1 Preliminary study

“Prospective study of peripheral arterial catheter infection and comparison with concurrently-sited central venous catheters.”

Even though the AC is indispensable for the management of the critically ill patients, there appears to be little information in medical literature on its potential to become colonized and/or cause CRBSI. Moreover, there is a lack of direct comparative data between AC and CVC infection rates within the same population of patients. This attitude is compounded by the guidelines of the CDC which state that ACs have low infection rates, and are rarely associated with bloodstream infection [31]. Contradictorily, the same guidelines also state that the rate of AC-related bloodstream infection is comparable to that of temporary CVCs (2.9 versus 2.3 per 1,000 catheter days) [31]. Which of these statements accurately reflects the true clinical situation formed the basis for the following guiding questions in this initial investigation,

- i) What are the colonization rates of ACs in this particular area of clinical practice, and how do these rates compare to those of CVCs in a cohort of patients?
- ii) What is the AC-CRBSI rate, and is there any accuracy in the CDC claim of ACs having low infection rates, and are rarely associated with bloodstream infection?
- iii) What are the risk factors associated with AC colonization?

The study demonstrated that AC colonization incidence rates were comparably close to CVC colonization rates (15.7 per 1,000 catheter days versus 16.8 per 1,000 catheter days). If colonization rates are to be regarded as the harbinger of potential CRBSI, this finding is significant because it indicated that ACs could be potential sources of sepsis along with concurrently managed CVCs. It contradicts the prevailing assumption that infection risk associated with the AC is much lower when compared to the CVC. The AC-related bloodstream infection rate for this study was low and may be attributed to the stringent adherence to infection control policies and relatively short *in situ* time of the ACs in this ICU. It would be arguably more accurate for the CDC to state that although the incidence of AC-related bloodstream infection is lower due to normal earlier removal of the ACs (ACs fail more readily and their clinical need ends earlier than CVCs, and infection risk rises with *in situ* time), colonization rates of ACs are comparable to those of temporary or short-termed CVCs when used for similar periods of time, and therefore the care and management of ACs should be accorded with the same degree of importance as CVCs, especially in a scenario where sepsis is suspected in a critically-ill patient.

Other findings related to colonization rates of ACs, such as time *in situ*, insertion site influences, and the clinical area where the procedure took place were consistent with findings from other studies [33-35, 39, 53, 73, 87, 116, 119, 173]. From this surveillance study and the examination of the published literature it became evident that the mechanisms underlying the

colonization of ACs needed further investigation. This was the impetus for the next three clinical observational studies undertaken.

7.1.2 Study 1

“A retrospective study to determine whether accessing frequency affects the incidence of microbial colonization in peripheral arterial catheters.”

The results from the initial investigation reinforced the finding that ACs do become colonized and may cause CRBSI but it was not known precisely how ACs became colonized. Although the three explanations for the process of microbial colonization in IVDs (extra-luminally, intra-luminally or haematogenous spread) are well documented, there is a need to determine if any of these processes occurred more frequently than the others. There was a common hypothesis that the more frequently an AC is accessed, the greater the likelihood of contamination and colonization. A nested, un-matched, case-control study was conducted using cases and controls from the previous service surveillance audit study, but with additional data collection to test the new hypothesis.

This study determined that there were no significant differences between the rates of accessing the ACs and their colonization, although a small effect cannot be excluded. Accessing frequency did not appear to be a major predisposing factor for the likelihood of AC colonization in the context of routine aseptic techniques. This suggested that IVD colonization via the intra-luminal route was a less common occurrence in the context of reasonable application of aseptic and infection control practices in the clinical area. The next study investigated the likelihood of microbial colonization via the extra-luminal route.

7.1.3 Study 2

“A prospective study to determine the degree of microbial colonization on the external and internal surfaces of concurrently-sited intravascular devices.”

It became evident that microbial colonization in IVDs might be more likely to occur via the extra-luminal route. Literature on the three mechanisms of IVD colonization are well documented but has been unable to reveal if one major route of IVD colonization occurs more frequently than another major route of colonization. Some past studies have suggested that microbial colonization originated from the skin surface surrounding the point of IVD entry, tracking downwards the external surface of the IVD, however, these studies fall short in examining the IVD in its entirety, failing to determine if there was a pattern of heavier microbial colonization on a particular segment of the IVD. We decided to examine each IVD in its entirety in order to determine if a pattern of microbial colonization existed on a particular segment of the IVD at the time of removal that might suggest where the colonization originated. The microbial colony counts at six different sites on each individual IVD were determined, allowing for repeated-measures comparisons of each IVD within itself.

It was decided to include all IVDs which were concurrently-sited and used in the clinical area to compare colonization rates between these devices unlike past studies which have isolated their investigations on either the CVC or the AC. There were physical differences in length among the IVDs, and the study sought to determine if this factor also influenced the rate of colonization. A 9-day minimum duration was used for selection in order to increase the proportion of colonized IVDs being processed.

The literature review exposed a lack of consistency with the methods used to determine the presence of microbial growth on IVDs. There is no consensus on the optimum diagnostic technique for establishment and definition of “colonization” and its relationship with CRBSI. This lack in agreement is due to some proponents supporting the removal of a suspected infected IVD for microbial analysis. Opponents against this practice argue that IVD removal on the hint of suspected infection is wasteful of resources, and advocate that microbial analysis could be performed with the IVD *in situ*. However, this would only count intra-luminal or

bloodstream CFUs and not account for micro-organisms colonizing on the extra-luminal surface of the IVD calling into question its efficacy to accurately diagnose CRBSI.

Microbial colonization on IVDs on its own, may have no known direct adverse effects, however, it is widely accepted as the harbinger of the pathogenesis of CRBSI or catheter-related bacteraemia and sepsis. Colonization is therefore regarded as a component criteria in the diagnosis of CRBSI demonstrated by the presence of microbial growth (≥ 15 CFUs) in a segment of the IVD (traditionally the distal tip of the IVD), along with accompanying symptoms of CRBSI, and a positive blood culture isolating the same antibiogram of the causative organism. Colonization can therefore also be viewed as a measure of a near miss of where CRBSI could have occurred but did not, because of other multi-factorial elements (such as the early intervention of prophylactic antibiotic therapy or the patient's immune system or simply inadequate time for sufficient growth to occur). The questions raised here are 1) how is microbial colonization in IVDs measured, and 2) whether what is measured is a full description of the clinically significant microbial biofilm growth on IVDs.

Microbiological techniques involving the removal of the IVD vary with the determination of microbial growth on the extra-luminal surface and/or the intra-luminal surface of the IVD. At first glance, it would appear that these techniques may reflect more accurately the presence of micro-organisms on these surfaces. However, two problems exist. There is much debate on variation in what is considered to be a significant quantity of bacterial growth [103]. Counts of micro-organisms can range from 5 CFUs to 1000 CFUs depending on the type of diagnostic method used [25, 103], and this raises the question of at which point does microbial biofilm growth in IVDs transform into entities whose risk to the patient is considered as clinically significant, when there is no general consensus of what constitutes an 'infected' IVD [67]. This also creates a dichotomy in determining at which point do the risks of an IVD outweigh its benefits for a critically-ill patient. Secondly, the majority of these techniques

tended to culture only the tips of the IVD, failing to take into account that colonization may occur at other segments of the IVD and not only at the tip.

Our study examined the IVD in its entirety whereby microbial growth in each different segment of each IVD could be compared to itself, and to other IVDs concurrently-sited in patients. It became apparent that the technique used to culture the different IVD segments in this study had to account for all the micro-organisms on both the extra-luminal and intra-luminal surfaces of the IVDs. Maki's semi-quantitative technique of IVD culture was adopted to extract micro-organisms from the IVD's extra-luminal surface because it was and is still the most common technique used in the laboratory determination of colonization [80]. A sterile wire was used to extrapolate microbial growth on the intra-luminal surface of IVDs. The wire was preferred over an endoluminal brush because the latter would require a different culture technique in broth, whereas the wire could be applied to the same culture media utilized in Maki's technique [80] ensuring comparison of microbial growth using the same culture media to maintain rigor and validity of the study.

The study revealed a pattern of heaviest microbial colonization at the proximal, external, intravascular segment of all IVD types compared to the middle or distal segments. Overall degree of colonization on the IVDs extra-luminal surface was greater than on the intra-luminal surface suggesting that colonization via the extra-luminal route was probably a more common occurrence compared to the other routes of microbial colonization. This finding, along with others such as the IVD insertion site, the area where IVD insertion took place, and the skill of the inserter, illuminated the hypothesis that the wound site created by IVD insertion may be a significant source of colonization, and raised the question if IVD wound site practices may contribute to the likelihood of colonization in IVDs.

7.1.4 Study 3

“Intravascular Devices: A Survey of Clinical Practices.”

As the study progressed, it became apparent that IVD colonization is caused by multiple factors, one being the environment in which these IVDs are managed and cared for on a daily basis. IVDs are mostly inserted by doctors but the care and management of the IVD is predominantly a nursing responsibility. Practice guidelines and institutional infection control protocols provide a reference point for nurses involved with the care and management of IVDs to implement best practice. However, there is no systematic or comparative data on the current state of IVD care, and little is known about how closely nurses adhered to the guidelines and protocols when caring and managing IVDs, and if any variations in practice contribute to increased microbial colonization in such devices.

It could be argued that the CDC guidelines, which advocate the specific care and management of IVDs are well known and likely to be complied with in the clinical setting. However, this is only an assumption and does not portray accurately the RNs’ concordance to these guidelines. This survey revealed that there was a less than ideal adherence to CDC evidence-based protocols in the clinical areas where IVDs were cared for and managed by RNs. In certain aspects of practice, such as the selection of IVD dressing supplies and the frequency of IVD dressing changes, adherence to protocols by intensive care nurses who manage IVD care daily, was less than those who had less experience with IVD care. Overall degree of concordance to CDC guidelines and institution infection control protocols was sporadic across all wards, reinforcing the validity of this part of the research programme to be undertaken. This may be attributed to a lack of awareness of and a diminished ability to access protocols to guide nursing practice.

RNs also displayed different preferences for sources of advice and information about IVD care and management. It became apparent that the RNs’ preferences for the method of accessing

this information did not match up with institution's implemented delivery of information, potentially causing a sub-optimal information flow. Information about care and management of IVDs although available, was not always utilized because its presentation may not be compatible with end-user preferences of modes of information delivery. The results obtained from the questionnaire provide a reference point for improvements in practice, education implementation and research promotion. The data allows a greater understanding of the nature of how RNs prefer to access evidenced-based resources in the clinical area. The greater implications from this finding is if evidenced-based resources are made more accessible to RNs, the care and management of IVDs in the clinical area may become more concordant to CDC guidelines, resulting in invariably decreasing IVD colonization and CRBSI rates, and reducing mortality and the socio-economic consequences of CRBSI.

7.2 Future Directions

This body of work has added a new and significant contribution to knowledge about IVD colonization, with implications for laboratory testing and diagnosis of CRBSI. However, some aspects of the work would benefit from further investigation.

- i) Definitions & terminology: The CDC has attempted to try and standardize the definitions of CRBSI and its associated terminology but other studies have also offered variations and justifications to support why their preferred terms and classifications of the infection should be adopted [67]. Until a worldwide general consensus on which applicable definitions and terms should be universally utilized, reference to CRBSI may still arguably remain confusing.
- ii) Routes of colonization: Microbial colonization occurring by different combinations of the three mechanisms might require different sampling and diagnostic techniques for each different mechanism. This research program is significant because it offers new knowledge about which of these three mechanistic routes of colonization occur

more often than the other, thereby giving clinicians a better understanding of the pathogenesis of microbial colonization. The finding of microbial colonization being greater at the proximal intravascular segments of all ACs, CVCs and PICCs calls for a review of the current clinical practice of only sending the tip of the IVD for microbiological analysis when an IVD is suspected of being a source of sepsis. It is still possible that when microbial biofilm originates at the site of insertion and grows down the length of the IVD, colonization detected at the IVD tip measured by simple culture techniques might be associated with biofilm changes at the other end of the IVD conducive to be released of mobilized particles that could cause CRBSI; this however would seem to be a very indirect way of conducting a diagnostic investigation.

- iii) Diagnostic technique: Current techniques available seem to fall short of being able to detect colonization both extra-luminally and intra-luminally. Clinical microbiologists should be challenged to devise a novel technique to detect micro-organisms colonizing on both the extra-luminal and intra-luminal surfaces of the IVD. Ideally, this technique could be applied without necessitating the removal of the IVD and validated for sensitivity and specificity for CRBSI risk. Until such a technique can be devised and deemed as the optimum technique to determine the presence of microbial colonization on all surfaces of IVDs, there will remain much debate about which diagnostic method is more efficacious than the other. This study has generated a challenge to develop a diagnostic method which is able to accurately determine microbial colonization and biofilm growth while the IVD is still *in situ* in a patient, but which could not be pursued by us due to time limitations.

- iv) CFU threshold: Current thresholds of microbial load defined by the CDC guidelines as criteria for positivity to IVD-related bloodstream infection range from 15 CFUs (using a semi-quantitative diagnostic technique) to 100 CFUs (using a qualitative diagnostic technique). There appears to be no universal agreement on what these microbial thresholds should be as differing trials have used differing diagnostic methods, and in the process altered these thresholds on the justification that the diagnostic methods used in their trials have better sensitivity and specificity. Moreover, little is known about what quintessentially is the exact bacterial load of each micro-organism needed in the bloodstream before it can become virulent and cause bloodstream infection. The answer to this is complex because other variable factors such as the patient's immunological status and existing co-morbidities need to be taken into account.
- v) Biofilm formation: The current diagnostic techniques utilized to detect the presence of these organisms appear to adopt a concept of either obtaining a smearing of microbial biofilm by quantitative and semi-quantitative techniques or by extrapolating free floating, planktonic micro-organisms by the qualitative techniques. More research is needed to investigate how microbial biofilms develop on IVDs and at which point do their growth become clinically significant when they occur in a patient. This study is not able to answer this question but suggests that further research involving *in vivo* studies of microbial biofilm formation and growth on IVDs be conducted. More research is needed to develop a more effective way of detecting the actual quantity and composition of a microbial biofilm along the entire length of the IVD to provide a more accurate estimate of microbial colonization on IVDs. Studies investigating microbial quorum sensing and the use of pulse field gel

electrophoresis are two such areas showing promise in developing a more effective and accurate way to account for microbial CFUs on IVDs.

- vi) Environmental factors: The findings of this research programme about the potentiality of the anatomical site of IVD insertion, place of IVD insertion, and the expertise of the inserter as factors which may influence the degree of microbial colonization sit well within the body of related literature. Numerous studies have recommended that maximal sterile barrier precautions and strict asepsis be implemented during IVD insertions [93, 111, 174] and this study reinforces those recommendations. This study brings about a new awareness of reflecting on the emergent nature and sub-optimal aseptic environmental conditions in which IVDs may sometimes be inserted, and therefore highlights the necessity of attentive IVD surveillance to reduce the potentiality of microbial colonization and CRBS

- vii) Educational resources to guide the care & management of IVDs:

Educational resources to guide the care and management of IVDs must be made easily accessible to the end-users needing that information. Health system management must devise better ways of delivering such information, while end users must realize they have a responsibility towards their ongoing training in information-related aspects of their practice. Information technology with its advancing ability to deliver practical solutions for improving the care of patients, may provide a practical solution for recording what is done during the care and management of IVDs and comparing that with CDC guidelines and institution protocols. Rehabilitative training may then be devised to overcome RN hesitation, reluctance, and otherwise failure to use available information. Periodic appraisal of the clinical education system should be regularly made in order for information to remain accessible and relevant to the needs of the end-user. The future of

healthcare should move towards a reduced tolerance for information ignorance and sub-optimal care, which means keeping staff well equipped with the necessary knowledge and skills of effectively accessing information.

CHAPTER 8

Conclusion

The purpose of this research study was to investigate the mechanism of microbial colonization on IVDs. The study began with an initial review of the available literature which revealed that there were only a few studies conducted on colonization rates of ACs and their potential to cause CRBSI. Further enquiry into the likely reasons for this lack of research in this area revealed that ACs may sometimes be regarded as devices of low infectivity, and therefore were not accorded the same degree of importance as other IVDs such as CVCs.

To ascertain if this assumption was true, we decided to compare the colonization rates of ACs and CVCs in a cohort of patients. The findings from this initial study led to the development of three studies: 1) to determine the predominant mechanism of AC colonization by reviewing AC accessing frequency and colonization rates; 2) to determine the degree of microbial colonization on the external and internal surfaces of concurrently-sited IVDs, and to establish if a spatial location of heaviest growth of micro-organisms exist on a particular segment of the IVD at time of removal; 3) to determine the degrees of concordance of nursing care and management of IVDs to CDC guidelines and institution protocols.

Three research methodologies, laboratory testing, statistical analyses, and a survey of nursing practices were undertaken. These studies generated new data on the nature of microbial colonization along the entire length of an IVD, which contributed to the knowledge related to IVD colonization rates. The study has also provided a snapshot of RNs' concordance to CDC guidelines and institution protocols with regard to the care and management of IVDs in the clinical area, and identified that microbial colonization on IVDs is multi-factorial.

In summary, the major findings of this work are:

- i) Establishing that AC colonization rates and CRBSI rates are similar to CVCs, reiterating the need to accord the same degree of importance to the AC as the CVC as a potential source of sepsis
- ii) Dispelling the notion that the more frequently an IVD is accessed, the greater the likelihood of contamination and colonization to occur.
- iii) IVD colonization via the intra-luminal route is less common when compared to the mechanism of microbial colonization on the external surface of the IVD.
- iv) Microbial colonization is heaviest at the proximal segment of all IVDs compared to the middle or distal segments, and that overall degree of colonization on the IVDs' internal surfaces is less than on the external surfaces.
- v) Discrepancies in concordance between the CDC guidelines and current nursing practice exist.
- iv) A knowledge-practice gap exists because the access to evidence-based protocols meant to provide vital information and guide nursing practice may be hindered by the incompatible preferences of end-users methods of seeking out such information.

The research programme has been successful in addressing the research problem and has achieved its objectives and goals. The research results have provided a new contribution to knowledge of how microbial colonization predominantly occurs, colonizing heavily on the extra-luminal surface of the proximal, intravascular portion of all IVDs, bringing into question current practices of culturing only tips of IVDs for determination of microbial growth and evidence of CRBSI. This finding also brings to light the deficits of current diagnostic

techniques used to detect microbial colonization and CRBSI, and the lack of universal consensus on its terminology and standardisation of diagnostic criteria used.

These problems along with the complexity of microbial colonization having a multi-factorial causation exemplifies the need for an iterative process that requires clinicians, researchers, policy formulators, decision-makers, and experts from all related disciplines of science to collaborate effectively to tackle the omnipresence of CRBSI in the clinical area.

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APPENDIX 1: Information sheet of Study 3



Department of Health & Human Services

INFORMATION SHEET:

Dear Colleague,

My name is David Koh, and I am a Registered Nurse currently pursuing my PhD studies at the University of Tasmania. My research topic for this study is:

To determine the current practices of the care and management of intravascular devices rendered by registered nurses (RNs).

Intravascular devices such as central venous catheters (CVCs), peripherally-inserted central catheters (PICCs), and arterial catheters (ACs) are indispensable tools that provide safe, reliable vascular access for the essential management of critically and chronically ill patients in the LGH. Unfortunately, most nosocomial infections in severely ill patients are caused by the very medical devices that are implanted to provide life-sustaining care.

The purpose of this study is to obtain a snapshot of the current practices rendered by Registered Nurses in the care and management of intravascular devices in their respective clinical areas. While practice may be guided by Nursing Practice Standards & Guidelines, there appears to be some variance in practice amongst different clinical areas.

With your help, I hope to identify if any differences in the care and management of IVDs exists, what influences this care, and identify techniques and strategies to enhance the care and management of these devices. I am inviting you to participate in my study by completing a short questionnaire, which will take about 20 minutes for you to complete.

This study has been approved by the Tasmania Health and Medical Human Research Ethics Committee. If you have any concerns of an ethical nature, or complaints about the manner in which the study is conducted, you may contact the Executive Officer of the Human Research Ethics Committee (Tasmania) Network on 6226 7479 or human.ethics@utas.edu.au. Please quote H10857 in all your correspondence.

Thank you for taking the time to provide important information that will help improve the care and management of IVDs in your clinical areas.

Kind Regards,

David Koh,
Registered Nurse & PhD Candidate,
LGH, CCMRT, UTAS.

APPENDIX 2: Consent form of Study 3

CONSENT FORM

Title of the project: To determine the current practices of care and management of intravascular devices rendered by Registered Nurses.

- 1) I have read and understood the 'Information Sheet' for this study.
- 2) The nature and the possible effects of the study have been explained to me.
- 3) I understand that my participation in the study involves filling out a survey, which would involve approximately 25 minutes of my time.
- 4) I understand that all research data will be treated as confidential, and survey results will be completely anonymous and unidentifiable.
- 5) Any questions that I have asked have been answered to my satisfaction.
- 6) I agree that the research data gathered for the study may be published provided that I cannot be identified as a subject. I understand that I will be able to access the thesis when it is submitted at the University of Tasmania.
- 7) I agree to participate in this investigation and understand that I may withdraw at any time without prejudice to my employment in the LGH.

Name of participant _____

Signature of Participant _____ **Date** _____

.....
I have explained this project and the implications of participation in it to this participant and I believe that the consent is informed and that he/she understands the implications of participation.

Name of Investigator: Mr David Koh (RN, PhD candidate, UTAS)

Signature of Investigator: _____ **Date** _____



APPENDIX 3: Questionnaire of Study 3

I.V.D. SURVEY QUESTIONNAIRE



CLIFFORD
CRAIG
MEDICAL
RESEARCH
TRUST

Questionnaire		Coding and Concordance Template
A) DEMOGRAPHICS:		
1) Are you a: (please circle)	(a) registered nurse level 1 (b) registered nurse level 2 (c) registered nurse level 3 (d) nurse educator (e) nurse unit manager	RN1 = 0 RN2 = 1 RN3 = 2 CNE = 3 NUM = 4
2) What full-time equivalent (FTE) hours do you work per fortnight? (please circle)	(a) 0.2 (b) 0.3 (c) 0.4 (d) 0.5 (e) 0.6 (f) 0.7 (g) 0.8 (h) 0.9 (i) full time	0.2 = 2 0.3 = 3 0.4 = 4 0.5 = 5 0.6 = 6 0.7 = 7 0.8 = 8 0.9 = 9 Full time = 0

<p>3) Which clinical area(s) do you mainly work in? (please circle all appropriate answers)</p> <p>(a) medical ward (b) surgical ward (c) intensive/coronary care (d) rehabilitation ward (e) others (please specify)</p>	<p>Medical ward = 0 Surgical ward = 1 Intensive/coronary care = 2 Rehabilitation ward = 3 Others = 4</p>
<p>4) Are you a (please circle) (a) DHHS* staff (b) Nursing agency staff</p> <p>(* DHHS = Department of Health & Human Services)</p>	<p>(a) DHHS staff = 0 (b) Nursing agency staff = 1</p>
<p>5) How long have you been in Nursing? _____ (years) OR _____ (months)</p>	<p>(No coding, actual numbers entered)</p>
<p>6) Did you train in Tasmania? (please circle) (a) Yes (b) No</p>	<p>(a) Yes = 1 (b) No = 0</p>
<p>7) Do you possess post-registration qualifications? (e.g. Grad Dip/Cert in Nursing) (a) Yes (please specify) _____ (b) No</p>	<p>(a) Yes = 1 (b) No = 0</p>
<p>B) MANAGEMENT OF INTRAVASCULAR DEVICES:</p>	
<p>1) How <u>often</u> do you inspect the CVC or Picline site and dressing?</p>	<p>Answers have been classified into the following categories:</p> <p>a) Once a shift or more frequently (bd, tds or qid) b) Daily c) when necessary or when using it d) don't check</p> <p>Answer (a) & (b) = TOTAL CONCORDANCE = 2 Answer (c) = PARTIAL CONCORDANCE (LOW) = 1 Answer (d) = NON CONCORDANCE = 0</p>
<p>2) What do you normally inspect the site for?</p>	<p><u>Answers have been classified into the following categories:</u></p> <p><u>SITE:</u> inflammation, redness, swelling, oozing, bleeding <u>LINE:</u> patency & functionality of device (i.e. leaking, dislodged, etc) <u>DRESSING:</u> dressing integrity (i.e. condition of dressing) <u>OTHER:</u> date & time of last dressing change, as per protocol Any answer containing any 3 or 4 of the above answer components</p>

	<p>= TOTAL CONCORDANCE = 3 Answer containing 2 the above answer components</p> <p>= PARTIAL CONCORDANCE (HIGH) = 2 Answer containing only 1 of the above answer components</p> <p>= PARTIAL CONCORDANCE (LOW) = 1 Answer containing none of the above answer components</p> <p>= NON CONCORDANCE = 0</p>
<p>3) In your opinion, which one of the following may best indicate to you that a CVC or Piccline may be showing indications of infection? (Circle only <u>ONE</u> answer)</p> <p>(a) when the site is red and inflamed locally (b) when the device has been <i>in situ</i> for more than 7 days (c) when the patient spikes a temperature above 38°C (d) when the site has exudate or is leaking (e) none of the above</p>	<p>Answer (e) = TOTAL CONCORDANCE = 2 All Other Answers = PARTIAL CONCORDANCE = 1 No Answer = NON CONCORDANCE = 0</p>
<p>4) What dressing supplies would you usually use to redress a CVC or Piccline dressing? (Circle AS MANY answers which are appropriate)</p> <p>(a) prepacked and sterile dressing set (b) normal saline (c) sterile water (d) chlorhexidine in alcohol 70% or Persist Plus™ swab sticks (e) povidone iodine (f) transparent adhesive dressing (e.g. Opsite, Tegaderm IV2000) (g) sterile gloves (h) ordinary gloves (i) other (please specify)</p>	<p>To attain TOTAL CONCORDANCE, Answers (a), (b or c), (d or e), (f), (g or h) must be included. = 4</p> <p>In addition, if (b) is used instead of (c), & (e) used instead of (d), PARTIAL CONCORDANCE (HIGH) is accorded = 3</p> <p>If only one of (b), (c), (d) or (e) is used in addition to the other supplies, PARTIAL CONCORDANCE (MODERATE) is awarded = 2</p> <p>If only one of (b), (c), (d), (e) or (f) is used, then PARTIAL CONCORDANCE (LOW) is accorded = 1</p> <p>If (a), (b) or (c), (d) or (e) & (f) in combination are not used, NON CONCORDANCE is awarded = 0</p>

<p>5) Briefly describe the routine changing of Artlines, CVCs, & Picline dressings in your current clinical area?</p>	<p>Answers should contain all of the following actions.</p> <ul style="list-style-type: none"> i) Hand-washing before procedure ii) Non-sterile gloves to remove old/soiled dressing iii) Wash hands after removal of dressing iv) Prepare dressing set & supplies (as per Q4) v) Sterile gloves or using aseptic technique, clean site with sterile water, inspect & let dry vi) Apply antiseptic (Persist sticks or Chlorhexidine 2% w Alcohol 70%) vii) Cover with transparent occlusive dressing viii) Date & time of dressing change documented ix) Dispose of rubbish x) Wash hands. <p>All steps adhered to, evidence of asepsis, dressing change frequency as per protocol = TOTAL CONCORDANCE = 3</p> <p>Dressing change frequency as per protocol, some minor omissions in dressing technique = PARTIAL CONCORDANCE (HIGH) = 2</p> <p>Dressing change frequency as per protocol, some major omissions in dressing technique = PARTIAL CONCORDANCE = 1</p> <p>Dressing change frequency NOT to protocol, no asepsis in dressing technique = NON CONCORDANCE = 0</p>
<p>6) How often do you change the following IVD dressings in your clinical area?</p> <p>(a) CVCs (excludes infusaports, vascaths & Hickman's catheters)</p> <p>(b) Piclines & Groshong catheters</p> <p>(c) Artlines (For ICU nurses only)</p>	<p>Answer to (a),(b) & (c) is weekly = CONCORDANCE = 1</p> <p>Other frequency of dressing change = NON CONCORDANCE = 0</p>
<p>7) Why do you change CVC or Picline dressings?</p>	<ul style="list-style-type: none"> i) SITE: Signs of infection (redness, inflammation, exudate) ii) LINE: Maintain position of device iii) DRESSING: Maintain dressing integrity (loose edges, come apart,

	bleeding, oozing) iv) PROTOCOL: Due to protocol or because dressing is due for routine change v) OTHERS: Other reasons 3 or more of above answers = CONCORDANCE = 2 1 to 2 answers = PARTIAL CONCORDANCE = 1 No answer = NON CONCORDANCE = 0
8) Will you apply a different type of dressing if the patient was diaphoretic, or if the site is bleeding or oozing? (a) Yes (please specify type of dressing) (b) No (please state reason why?)	(a) Yes , gauze secured with transparent occlusive dressing The CDC recommends that a gauze dressing be applied in this instance and that the dressing be changed every 48hrs until it can be replaced with a transparent occlusive dressing YES = CONCORDANCE = 1 NO = NON CONCORDANCE = 0
9) What do you normally do to the unused lumens of CVCs or Picclines? (a) apply a one-way valve (b) apply a positive-pressure valve (c) leave the administration giving set attached to the CVC or Piccline for later use (d) other (please specify)	Answer (b) or (d) = CONCORDANCE = 2 Answer (a) = PARTIAL CONCORDANCE = 1 Answer (c) = NON CONCORDANCE: = 0
10) How often do you change the caps, bungs or valves on the end of the lumens of the CVC or Picclines? (a) daily (b) every 72hrs (c) after every administration of IV antibiotics &/or IV fluids (d) do not change them at all (e) during routine dressing changes	Answer (e) = CONCORDANCE = 3 Answers (b) & (c) = PARTIAL CONCORDANCE (HIGH) = 2 Answer (a) = PARTIAL CONCORDANCE (LOW) = 1 Answer (d) = NON CONCORDANCE = 0

<p>(For ICU nurses only)</p> <p>11) How often do you change the caps on the hubs of the <u>Arterial line</u>?</p> <p>(a) daily (b) every 72hrs (c) after every blood gas sampling (d) do not change them at all (e) during routine dressing changes (f) other (please specify)</p>	<p>Answer (c) = CONCORDANCE = 3 Answer (a) = PARTIAL CONCORDANCE (HIGH) = 2 Answers (b) & (e) = PARTIAL CONCORDANCE (LOW) = 1 Answer (d) = NON CONCORDANCE = 0</p>
<p>12) Do you normally flush the lumens of the CVC or Picline to maintain patency when not in use?</p> <p>(a) Yes (b) No (please proceed to question 15)</p>	<p>Answer (a) = CONCORDANCE = 1 Answer (b) = NON CONCORDANCE = 0</p>
<p>13) What solution do you normally use to flush the CVC or Picline with?</p> <p>(a) 5mls of normal saline in each lumen (b) 5mls of heparinised saline (50 iu in 5mls) in each lumen (c) 10mls of normal saline in each lumen (d) 10mls of heparinised saline (50 iu in 5mls) in each lumen</p>	<p>Answer (c) = CONCORDANCE = 2 Answers (a), (b) & (d) = PARTIAL CONCORDANCE = 1 Answer (e)-if "do not flush" = NON CONCORDANCE = 0</p>
<p>14) How often do you normally flush the unused lumens of the CVC or Picline?</p> <p>(i) <u>without</u> a positive pressure valve?</p> <p>(a) daily (d) once a shift (b) every 48-72hrs (e) less frequently than 72hrs (c) as ordered (f) other (please specify)</p> <p>(ii) <u>with</u> a positive pressure valve?</p> <p>(a) daily (d) once a shift (b) every 48-72hrs (e) less frequently than 72hrs (c) as ordered (f) other (please specify)</p>	<p>Answer (d) = CONCORDANCE = 3 Answers (a) & (c) = PARTIAL CONCORDANCE (HIGH) = 2 (c)- if bd, tds or qid Answers (b) & (e) = PARTIAL CONCORDANCE (LOW) = 1 Answer (f) if "do not flush" = NON CONCORDANCE = 0</p> <p>Answer (f) "weekly" = CONCORDANCE = 2 Answers (a) to (e) = PARTIAL CONCORDANCE = 1 Answer (f) if "do not flush" = NON CONCORDANCE = 0</p>

15) Please describe how you would normally decontaminate the hub or port of the CVC or Picline when administering intravenous antibiotics or when connecting to an administration giving set?	Rigorous friction rub the hub with alcohol swab (or chlorhexidine) for 60 secs, let dry (30secs), before connecting up admin set. CONCORDANCE = 2 PARTIAL CONCORDANCE = 1 NON CONCORDANCE = 0
16) Are dressing changes of Artlines, CVCs and Piclines of a lesser priority of routine nursing care, on occasions when you get very busy with other nursing interventions for your patients? (a) Yes (b) No (c) Possibly (please provide an explanation)	THIS QUESTION SEEKS NURSES' PERCEPTION AND TRENDS, AND NO CONCORDANCE SCORE IS ALLOCATED
17) In your opinion, how long should short-term, non-tunnelled CVCs be left in-situ in a patient and why? (excludes infusaports, vascaths, & Hickman's catheters)	THIS QUESTION SEEKS NURSES' PERCEPTION AND TRENDS, AND NO CONCORDANCE SCORE IS ALLOCATED
18) In your opinion, how long should a Picline be left <i>in situ</i> in a patient and why?	THIS QUESTION SEEKS NURSES' PERCEPTION AND TRENDS, AND NO CONCORDANCE SCORE IS ALLOCATED
19) In your opinion, how long should an Artline be left <i>in situ</i> in a patient and why?	THIS QUESTION SEEKS NURSES' PERCEPTION AND TRENDS, AND NO CONCORDANCE SCORE IS ALLOCATED
20) Under what circumstances should a CVC or Picline be preserved for continued use beyond the time specified in protocol?	THIS QUESTION SEEKS NURSES' PERCEPTION AND TRENDS, AND NO CONCORDANCE SCORE IS ALLOCATED
C) INFECTION CONTROL MEASURES:	
1) In your opinion, which ONE of the following would be the most effective measure to reduce Artline, CVC or Picline-related infections? (Circle ONE answer only) (a) effective vigilant handwashing (b) routine Artline, CVC and Picline dressing changes (c) regular re-sites of Artline, CVC and Picline devices (d) prompt removal of Artline, CVC and Picline when not required	Answer (a) = CONCORDANCE = 2 All other answers = PARTIAL CONCORDANCE = 1

<p>2) In your opinion, which of the following would be the most effective handwashing practice in your clinical area? (Circle ONE answer only)</p> <p>(a) conventional handwashing using antiseptic soap solution and tap water (b) conventional handwashing using ordinary soap and tap water (c) thoroughly "rubbing" hands with waterless, alcohol-based antiseptic gels (d) a 5-minute handwash using a scrub brush and povidone iodine (e) none of the above as sterile gloves should be worn when handling Artlines, CVCs and Picclines</p>	<p>Answers (a),(c) & (d) = CONCORDANCE = 2 Answers(b) & (e) = PARTIAL CONCORDANCE = 1</p>
<p>3) Which antiseptic solution do you normally use in your clinical area to disinfect the skin before the insertion of an Artline, CVC or Piccline?</p> <p>(a) normal saline (c) chlorhexidine in 70% alcohol (b) povidone iodine (d) others (please specify)_____</p>	<p>Answers (c) & (d) = CONCORDANCE = 2 Answers (a) & (b) = NON CONCORDANCE = 1</p>
<p>4) Which type of solution(s) do you usually use to clean and disinfect the site of the Artline, CVC or Piccline during routine dressing changes in your practice area? (Circle ALL answers that are appropriate)</p> <p>(a) sterile water (c) povidone iodine (b) normal saline (d) chlorhexidine in 70% alcohol (e) others (please specify)_____</p>	<p>Answers (a) & (c) &/or (e) = CONCORDANCE = 2 Answer (b) = PARTIAL CONCORDANCE = 1 Answer (c) = NON CONCORDANCE = 0</p>
<p>5) What is your unit's normal practice in the routine changing of dressings for Artlines, CVCs and Picclines?</p> <p>(a) routine change every 24 hours (c) routine change every 5 days (b) routine change every 3 days (d) routine change every week (e) others (please specify)_____</p>	<p>Answer (d) = CONCORDANCE = 1 All other answers = NON CONCORDANCE = 0</p>

<p>6) On what occasions might you change the dressing of the Artline, CVC or Piccline more frequently than your unit's normal practice? (Circle ALL answers that are appropriate)</p> <p>(a) when the Artline, CVC or Piccline site is oozing with blood underneath (b) when the Artline, CVC or Piccline site is red and inflamed (c) when the transparent dressing of the Artline, CVC or Piccline site is partially lifting (d) when the patient requests you to do so</p>	<p>Answer (a) &(b) = CONCORDANCE = 2 Answer (c) = PARTIAL CONCORDANCE = 1 Answer (d) = NON CONCORDANCE = 0</p>
<p>7) How often are the infusion administration sets usually replaced in your clinical area in the following scenarios?</p> <p>i) Routine change _____ hrs/days ii) After the administration of blood, and/or blood products? iii) After the administration of TPN (For ICU nurses only) iv) After the administration of Propofol? _____ hrs/days</p>	<p>Answer (i) 72 hours or 3 days Answer (ii) immediately after transfusion or not exceeding 4 hours of last usage Answer (iii) every 24 hours if lipid-based or as indicated by pharmacy Answer (iv) every 24 hours CONCORDANCE = 1 NON CONCORDANCE = 0</p>
D) ENVIRONMENT:	
<p>1) In your opinion, which statement below best describes "<u>maximal sterile barrier precautions</u>"? (Circle only ONE answer only)</p> <p>(a) the use of sterile instruments, sterile drapes, gown, gloves and mask during the CVC or Piccline insertion procedure (b) the use of sterile gloves and sterile instruments only (c) assigning one dedicated nurse only to care for the patient during the shift (d) patient is nursed in a single room with door shut and visitors restricted</p>	<p>Answer (a) = CONCORDANCE = 1 All other answers = NON CONCORDANCE = 0</p>

<p>2) To the best of your knowledge, what does the term “<u>strict asepsis</u>” refer to? (Circle only <u>ONE</u> answer only)</p> <p>(a) handwashing before procedure, use of sterile equipment and sterile gloves (b) handwashing before procedure, use of sterile equipment, sterile gloves, gown and mask (c) handwashing and the use of gloves when performing any procedure (d) “one-touch technique” observed during dressing changes</p>	<p>Answers (a) & (b) = CONCORDANCE = 1 Answers (c) & (d) = NON CONCORDANCE = 0</p>
<p>3) In your opinion, where would the ideal place for an insertion of a CVC or Piccline be carried out in? (Circle <u>AS MANY</u> answers which are appropriate)</p> <p>(a) Treatment room of ward (d) DEM (b) Theatre (e) at the patient’s bedside as long as maximal (c) ICU sterile barrier precautions are observed</p>	<p>THIS QUESTION SEEKS NURSES’ PERCEPTION. AND NO CONCORDANCE SCORE IS ALLOCATED</p>
<p>4) In your opinion, which type of patient do you think is most susceptible to intravascular device-related bloodstream infection? (Circle <u>ONE</u> answer only)</p> <p>(a) immunocompromised patients (b) patients in sepsis (c) patients receiving IV antibiotics (d) patients on continuous intravenous fluid therapy (e) any patient who has an intravascular device <i>in situ</i></p>	<p>THIS QUESTION SEEKS NURSES’ PERCEPTION. AND NO CONCORDANCE SCORE IS ALLOCATED</p>
<p>5) In your opinion, which micro-organism(s) is(are) most likely to cause catheter-related bloodstream infection?</p>	<p>NURSE PERCEPTION, NO CONCORDANCE SCORE ALLOCATED <i>Staphylococcus epidermidis, Staphylococcus aureus (including MRSA), yeasts, enterococci, coliform were some of the answers given.</i></p>

E) RESOURCES & TRAINING	
<p>1) Where would you go to if you needed information about the care and management of Artlines, CVCs or Picclines? (Please RANK answers according to preference: 1 = most preferred, 4 = least preferred)</p> <p>_____ Unit's protocol folder _____ Hospital guidelines folder _____ DHHS intranet website (e.g. CI-SCaT) _____ Internet general search website (e.g.: Google.com) _____ Other (please specify)</p>	<p>NO CORRECT OR INCORRECT ANSWER.</p> <p>THIS QUESTION SEEKS TO GATHER NURSES' PREFERENCES. NO CONCORDANCE SCORE IS ALLOCATED.</p>
<p>2) Who would you go to if you needed information about the care and management of Artlines, CVCs or Picclines? (Please RANK answers according to preference: 1 = most preferred, 6 or 7 = least preferred)</p> <p>_____ Nurse Unit Manager _____ Nurse Educator _____ Senior or more experienced nursing staff _____ Infection Control Nurse _____ Call another ward or clinical area for advice (e.g.Holman Clinic, RHH) _____ Other nursing staff _____ Other (please specify)</p>	<p>NO CORRECT OR INCORRECT ANSWER.</p> <p>THIS QUESTION SEEKS TO GATHER NURSES' PREFERENCES. NO CONCORDANCE SCORE IS ALLOCATED.</p>
<p>3) Which is your <u>most preferred method</u> of accessing information in the clinical area (Please RANK answers according to preference: 1=most preferred, 4 or 5 =least preferred)</p> <p>_____ A document folder containing standards, guidelines & protocols of clinical practice _____ A specific website portal available on your ward computer (intranet) _____ A general website on the internet like Google _____ A specific person you can call for consultation from 9am – 5pm (e.g. Infection Control Nurse) _____ Other (please specify)</p>	<p>NO CORRECT OR INCORRECT ANSWER.</p> <p>THIS QUESTION SEEKS TO GATHER NURSES' PREFERENCES. NO CONCORDANCE SCORE IS ALLOCATED.</p>

4) How beneficial would an in-service education session specifically on the care and management of Artlines, CVCs and Picclines be to you? (a) Much benefit (b) A little benefit	(c) Some benefit (d) No benefit	NO CORRECT OR INCORRECT ANSWER. THIS QUESTION SEEKS TO GATHER NURSES' PREFERENCES. NO CONCORDANCE SCORE IS ALLOCATED.
5) Would you be willing to attend this session at your own time? (a) Yes (b) No	(c) It depends (please provide reason)	NO CORRECT OR INCORRECT ANSWER. THIS QUESTION SEEKS TO GATHER NURSES' PREFERENCES. NO CONCORDANCE SCORE IS ALLOCATED.

 **THANK YOU VERY MUCH FOR COMPLETING THIS SURVEY!!** 

**PLEASE PUT COMPLETED QUESTIONNAIRE INTO THE SELF-ADDRESSED ENVELOPE
PROVIDED AND SEND IT VIA INTERNAL MAIL**